IS 11018-1 (1984): Expression of properties of cathode-ray oscilloscopes, Part 1: General [LITD 8: Electronic Measuring Instruments, Systems and Accessories]

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IS : 11018 (Part 1)-1984
IEC Pub 351-1-1976

(Reaffirmed 2000)

Indian Standard

EXPRESSION OF THE PROPERTIES OF CATHODE-RAY OSCILLOSCOPES

PART 1 GENERAL

INDIAN STANDARDS INSTITUTION

UDC 621·397·3 : 621·317·799

IS : 11018 (Part 1)-1984
IEC Pub 351-1-1976

Indian Standard

EXPRESSION OF THE PROPERTIES OF CATHODE-RAY OSCILLOSCOPES

PART 1 GENERAL

National Foreword

This Indian Standard (Part 1), which is identical with IEC Pub 351-1-1976 'Expression of the properties of cathode-ray oscilloscopes, Part 1 General', issued by the International Electrotechnical Commission (IEC), was adopted by the Indian Standards Institution on the recommendation of the Electronic Measuring Equipment Sectional Committee and approved by the Electronics and Telecommunication Division Council.

Cross Reference

International Standard	*Corresponding Indian Standard*
IEC Pub 106-1974 Recommended methods of measurement of radiated and conducted interference from receivers for amplitude-modulation, frequency-modulation and television broadcast transmissions (*second edition*)	IS : 4546-1983 Methods of measurement of radiated and conducted interference from receivers for amplitude-modulation, frequency modulation and television broadcast transmissions (*first revision*) (Technically equivalent)
IEC Pub 348-1978 Safety requirements for electronic measuring apparatus (*second edition*)	IS : 9858-1981 Safety requirements for electronic measuring apparatus (Technically equivalent)
IEC Pub 359-1971 Expression of the functional performance of electronic measuring equipment.	IS : 9176-1979 Method for specifying the functional performance of the electronic measuring equipment (Technically equivalent)

Note — The French text given in the IEC Publication has been dropped while adopting the publication as Indian Standard.

Electronic Measuring Equipment Sectional Committee, LTDC 21 [Ref : Doc : LTDC 21 (678)]

Adopted 30 August 1984

Gr 14

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CONTENTS

1. General

1.1 *Scope*

1.1.1 This standard applies to general-purpose cathode-ray oscilloscopes (hereinafter called "oscilloscopes") for measuring electrical quantities, containing at least:

— a cathode-ray tube,
— a vertical deflection device,
— a time base and/or a horizontal deflection device.

1.1.2 This standard is also applicable to:

— multitrace oscilloscopes (Sub-clause 2.1.4) when they comply with Sub-clause 1.1.1,

— complete assemblies of oscilloscopes with detachable or incorporated parts, e.g. probes or interchangeable plug-in units.

1.1.3 This standard applies also to oscilloscopes for measuring non-electrical quantities, when it is possible to express their performance in terms of an electrical quantity which represents the non-electrical quantity.

1.1.4 This standard is concerned with the qualities of the cathode-ray tubes only when these are necessary for the evaluation of oscilloscopes. The intrinsic qualities of cathode-ray tubes will be dealt with in another standard.

1.1.5 Some portions of this standard may be applicable, by special agreement between manufacturer and user, to observation or special-purpose oscilloscopes, e.g.:

— sampling oscilloscopes,
— characteristic curve tracers,
— vectorscopes;
— radial deflection oscilloscopes,
— storage oscilloscopes.

1.1.6 Safety requirements are not dealt with in this standard. Unless otherwise agreed upon, devices such as those in Clause 1 shall comply with IEC Publication 348, Safety Requirements for Electronic Measuring Apparatus.

1.2 *Object*

The object of this standard is the standardization of methods of expression of the properties of cathode-ray oscilloscopes and more particularly:

— the definition of special terminology and catalogue data related to these types of apparatus;

— the specification of conditions and methods for testing these types of apparatus in order to verify compliance with properties claimed or specified by the manufacturer.

2. Terminology

For the purpose of this standard, it has been agreed that the special meanings contained in the following clauses shall apply. Definitions taken from the International Electrotechnical Vocabulary are shown by the reference to I.E.V. Group 07 or 20.

2.1 *Types of oscilloscopes*

2.1.1 *Cathode-ray oscilloscope*

An apparatus for measurement or observation purposes which uses the deflection of one or more electron beams to produce a display which represents the instantaneous value of functions of varying quantities, one of them, in general, being time.

2.1.2 *Measuring oscilloscope*

An oscilloscope which, by means of scales or calibrated switch positions associated with the controls of deflection and time coefficients, is suitable for measuring with defined accuracy.

Note. — A measuring oscilloscope may, or may not, have built-in calibrating devices. It is further necessary to distinguish between oscilloscopes in which measurement is made by a calibrated graticule and oscilloscopes in which the graticule is not used directly, except as a means of referring to another calibrated control.

2.1.3 *Observation oscilloscope*

An oscilloscope which is suitable only for the qualitative observations of varying quantities, being without defined accuracy.

Note. — Some observation oscilloscopes have sufficient linearity and stability of performance to permit their use for measuring purposes after calibration by external means.

2.1.4 *Multitrace oscilloscope*

An oscilloscope with which it is possible to measure or observe simultaneously several electrical phenomena, each phenomenon being displayed on a separate trace.

Note — This result may be obtained by:
- a tube with several guns (multi-beam),
- a tube with one divided beam (split-beam),
- one beam and electronic switching (displayed alternately or chopped),
- an oscilloscope with several tubes (multi-tube).

2.2 *Cathode-ray tube*

An electron-beam tube in which the beam can be focused to a small cross-section on a surface and varied in position and intensity to produce a pattern either visible or otherwise detectable (I.E.V. 07-30-090).

2.2.1 *Cathode-ray tube size*

The overall dimensions of the face of the cathode-ray tube (external diameter of tubes with a circular face, the height and width of tubes having a rectangular face).

2.2.2 *Screen*

The surface of the tube upon which the visible pattern is produced (I.E.V. 07-30-145).

2.2.3 *Spot*

The small area of the screen surface instantaneously affected by the impact of the electron beam. (I.E.V. 07-30-160).

2.2.3.1 *Spot size and focus*

Under consideration.

2.2.4 *Measuring area*

That part of the screen within which measurements can be made with defined accuracy.

Note. — This is not necessarily the whole screen area within which a display can be obtained.

2.3 *General terms*

2.3.1 *Amplifiers and attenuators*

2.3.1.1 *Amplifier*

The circuitry which provides amplification of the voltage applied to the input terminals to obtain a deflection or other function.

2.3.1.2 *Attenuator*

A device which provides the attenuation of a voltage according to defined ratios.

2.3.2 *Accessory parts*

2.3.2.1 *Plug-in unit*

A removable part of an oscilloscope, adapted by plug and socket connection to compose a set intended to perform a particular function.

Examples of plug-in units:

— high sensitivity amplifier,
— wide-band amplifier,
— difference amplifier,
— electronic beam switching.

2.3.2.2 *Probe*

An input device of an oscilloscope made as a separate unit and connected by a flexible cable which transmits, in a suitable manner, the measuring quantity to the oscilloscope.

2.3.3 *Terms concerning waveform*

2.3.3.1 *Departures from a sine-wave*

The distortion of a sine-wave is defined by the difference between the peak value and $\sqrt{2}$ times the r.m.s. value and/or by limits as specified by value β of the formula:

$$y = a\,(1 \pm \beta) \sin \omega t$$

2.3.3.2 *Square wave*

A periodic wave that alternately for equal lengths of time assumes two fixed values, the time of transition being negligible in comparison with that length.

2.3.3.3 *Rectangular pulse*

A waveform having a profile approximately rectangular, the rise and fall times being sufficiently short in comparison with the pulse duration.

2.4 *Terms concerning preparation of tests*

2.4.1 *Warm-up time*

The time interval after switching on the oscilloscope under reference conditions, necessary for it to comply with all accuracy requirements.

2.4.2 *Adjustment*

The operation by means of which certain adjusting parts are set according to the manufacturer's directions, so as to cause the oscilloscope to conform with the specified accuracy.

Note. — This process is termed *preliminary adjustment* when it is carried out before tests and *readjustment* during tests. With oscilloscopes having built-in calibrating devices, calibration may form a part of preliminary adjustments.

2.4.3 *Centring*

The process by which the spot (or the base line drawn by the spot) is positioned to the centre of the screen.

2.5 *Terms related to accuracy*

2.5.1 *Quantities related to the function of the oscilloscope and terms related to conditions of operation, transport and storage*

2.5.1.1 *Performance characteristic*

One of the quantities assigned to an oscilloscope in order to define by values, tolerances, ranges, etc., the performance of the oscilloscope.

Note. — The term "performance characteristic" does not include influence quantities (see Note to Sub-clause 2.5.1.2).

2.5.1.2 *Influence quantity*

Any quantity, generally external to an oscilloscope, which may affect the performance of the oscilloscope.

Note. — Where a change in a performance characteristic affects another performance characteristic, it is referred to as an influencing characteristic (see Sub-clause 2.5.3.5).

2.5.1.3 *Reference value*

A single value of an influence quantity at which the oscilloscope (or accessory) complies with the requirements concerning intrinsic errors.

2.5.1.4 *Reference range*

A range of values of an influence quantity within which the oscilloscope (or accessory) complies with the requirements concerning intrinsic errors.

2.5.1.5 *Reference conditions*

A set of values with tolerances (reference values), or of restricted ranges (reference ranges) or influence quantities, and if necessary of influencing characteristics, specified for making comparison and calibration tests.

2.5.1.6 *Rated range of use*

The range of values for an influence quantity within which the requirements concerning operating error are satisfied.

2.5.1.7 *Rated operating conditions*

The whole of the effective ranges for performance characteristics and rated ranges of use for influence quantities within which the performance of the apparatus is specified.

2.5.1.8 *Limit conditions of operation*

The whole of the ranges of values for influence quantities and performance characteristics (beyond the rated ranges of use and effective ranges respectively) within which an apparatus can function without resulting damage or degradation of performance when it is afterwards operated under rated operating conditions.

Note. — The limit conditions will, in general, include overload.

2.5.1.9 *Conditions of storage and transport*

The whole of the conditions of temperature, humidity, air pressure, vibration, shock, etc., within which the apparatus may be stored or transported in an inoperative condition, without resulting damage or degradation of performance when it is afterwards operated under rated operating conditions.

2.5.2 *Values related to quantities*

2.5.2.1 *Rated value*

The value (or one of the values) of a quantity to be measured, observed, supplied or set, which the manufacturer has assigned to the oscilloscope.

2.5.2.1.1 *Rated vertical (horizontal) deflection*

Distance measured in the vertical (horizontal) direction between the limits of the measuring area.

2.5.2.2 *Rated range*

The range, of a quantity to be measured, observed, supplied or set, which the manufacturer has assigned to the oscilloscope.

2.5.2.3 *Effective range*

That part of the rated range where measurements can be made or quantities be supplied within the stated limits of error (I.E.V. 20-40-035 modified).

2.5.3 *Terms related to the specification of performance*

2.5.3.1 *Performance*

The degree to which the intended functions of an oscilloscope are accomplished.

2.5.3.2 *Error*

2.5.3.2.1 *Absolute error*

The error expressed algebraically, in the unit of the measured or supplied quantity.

a) For a measuring apparatus, the error is the indicated value of the measured quantity minus its true value.

b) For a supply apparatus, the error is the true value of the quantity supplied minus its rated, indicated or preset value.

Notes 1. — The true value of a quantity is the value that would be measured by a measuring process having no error.

In practice, since this true value cannot be determined by measurement, a conventionally true value, approaching the true value as closely as necessary (having regard to the error to be determined), is used in place of the true value. This value may be traced to standards agreed upon by the manufacturer and the user, or to national standards. In both cases the uncertainty of the conventionally true value shall be stated.

2. — The above definitions do not apply to deflection coefficients or time coefficients of an oscilloscope as these coefficients are neither measured nor supplied quantities.

2.5.3.2.2 *Relative error*

The ratio of the absolute error to a stated value.

2.5.3.2.3 *Absolute error of a deflection (time) coefficient*

The difference between the measured value and the rated value of a deflection (time) coefficient.

Note. — The measured value of a coefficient is the value that is calculated from the deflection measured on the screen when a known signal is applied to input terminals.

2.5.3.2.4 *Relative error of a deflection (time) coefficient*

The ratio of the absolute error of a deflection (time) coefficient to the rated value.

2.5.3.2.5 *Percentage error*

The relative error expressed as a percentage.

2.5.3.2.6 *Relative linearity error of a coefficient*

Relative linearity error of a coefficient is given by whichever of the following two expressions has the greater value without regard to sign:

$$\frac{K_a - K_b}{K_a} \quad \text{or} \quad \frac{K_a - K_c}{K_a}$$

where:

K_a = the average deflection coefficient measured over the central 80% region of the rated deflection

K_b and K_c = the average deflection coefficient for each of the two extreme 10% regions of the rated deflection.

Note. — This definition of linearity is intended solely for oscilloscopes and takes account of the fact that departures from linearity are generally negligible in the central 80% of the rated deflection but become significant in the extreme 10% regions.

2.5.3.3 *Intrinsic error*

The error determined under reference conditions.

2.5.3.4 *Operating error*

The error determined under rated operating conditions (Sub-clause 2.5.1.7).

2.5.3.5 *Influence error*

The error determined when one influence quantity assumes any value within its rated range of use (or an influencing performance characteristic assumes any value within its effective range), all others being at reference condition.

Note. — When over the whole rated range of use a substantially linear relationship exists between the influence error and the effect causing it, the relationship may be conveniently expressed in coefficient form.

2.5.3.6 *Limits of error*

The maximum values of error assigned by the manufacturer to a measured or supplied quantity of an oscilloscope operating under specified conditions.

2.5.3.7 *Limits of error of a deflection (time) coefficient*

The maximum values of error assigned by the manufacturer to a deflection (time) coefficient of an oscilloscope operating under specified conditions.

2.5.4 *Variation*

The difference between the values of a measured or supplied quantity when one influence quantity assumes successively two specified values within its rated range of use, the others being at reference conditions.

Note. — A variation may be considered as absolute or relative in the same way as an error.

2.6 *Terms related to vertical (horizontal) deflection*

2.6.1 *Vertical (horizontal) deflection*

The deflection of the spot when a signal is applied to the vertical (horizontal) input, the horizontal (vertical) system being non-operative.

2.6.1.1 *Vertical (horizontal) deflection coefficient*

The ratio between the voltage and the length of vertical (horizontal) deflection produced by this voltage.

Note. — Deflection coefficients are expressed in the dimension voltage (or current) per unit length, and a coefficient of 5 V/cm is larger than 5 mV/cm. This means, accordingly, that the sensitivity with a coefficient of 5 V/cm is smaller than with a coefficient of 5 mV/cm.

2.6.2 *Instability of the spot position*

This term comprises the following three phenomena which occur whether a signal is present or not.

2.6.2.1 *Drift*

The (unwanted) generally slow and continuous deviation of the spot as a function of time.

a) Long-term drift

Maximum deviation of the spot recorded during 1 h.

b) Short-term drift

Maximum deviation of the spot recorded during the most unfavourable minute within 1 h total recording.

Note. — Drift has, in general, vertical and horizontal components which can be measured separately, the values of the influence quantities being held constant in every case.

2.6.2.2 *Periodic and/or random deviations (PARD)*

Unwanted deflections of a periodic (hum, ripple, etc.) and/or random (noise, fluctuation, etc.) nature due to various causes and appearing on the screen in the absence of a signal or added to the display of an input signal.

2.6.2.3 *Zero shift*

The movement of the spot or of the trace without any signal due to the effect of a prescribed change in a specified influence quantity.

Note. — The zero shift is generally not instantaneous. The maximum value of this shift shall be determined during a specified time interval.

2.6.3 *Pulse and frequency responses*

2.6.3.1 *Frequency response: —3 dB bandwidth*

Band of frequencies within which the value of the reciprocal of the deflection coefficient does not differ by more than —3 dB from its value at reference frequency.

Note. — This definition does not take into account any rise or other irregularity in the frequency response between reference frequency and the —3 dB points, as this would cause irregularities concerning pulse response defined in Sub-clauses 2.6.3.2, 2.6.3.3 and 2.6.3.4.

2.6.3.2 *Rise (fall) time*

Time interval within which the current or voltage of the edge of a rectangular pulse passes from 10% to 90% (from 90% to 10%) of its steady-state amplitude (Figure 1, page 74).

Note. — In the case of amplifiers having a proper pulse response, the following relationship between rise time (t_r), expressed in nanoseconds, and the upper limit of the —3 dB bandwidth (B), expressed in megahertz, is approximately true:

$$t_r = \frac{350}{B}$$

2.6.3.3 *Overshoot*

That part of the initial response which exceeds the steady-state value of the response to a rectangular (square) pulse (Figure 1). It is expressed as a percentage of the steady-state value.

2.6.3.4 *Pulse tilt*

The relative difference between the initial and final amplitude of the representation of a rectangular pulse (Figure 2a, page 75) or of a square wave (Figure 2b, page 75) ignoring overshoot and other distortions (see Sub-clause 2.6.3.2). It is expressed as a percentage of the initial amplitude and for a specified time period:

$$\text{pulse tilt} = \frac{\Delta A}{A} 100 \quad \text{(Figure 2a).}$$

Note. — When tests for pulse tilt are performed with a symmetrical square wave, the formula:

$$\text{pulse tilt} = \frac{2\,\Delta A}{A_2} 100 \quad \text{(Figure 2b)}$$

may be used for convenience.

2.6.3.5 *Other pulse distortions*

Distortions other than those defined in Sub-clauses 2.6.3.2, 2.6.3.3 and 2.6.3.4 are identified by the titles to Figures 3a to 3g, pages 76 and 77; verbal descriptions are not given, as the diagrams are sufficient in themselves for the effects to be identified. These distortions may appear on the display either singly, in groups or combined, depending on the selected time coefficient.

When these distortions have durations comparable to the rise time t_r, the diagrams show the rise time as having finite magnitude. Conversely, when the distortions can occupy time durations up to several orders of magnitude greater than the rise time, the diagrams show the rise time as zero. This is particularly so in the case of Figure 3g, Defect of sustained step response, when the effects are thermal in origin.

2.6.4 *Positioning*

The vertical or horizontal movement of the trace obtained by actuating the appropriate control.

2.6.5 *Input impedance*

The impedance measured between the input terminals of the oscilloscope.

Note. — It is represented by the values of a resistor and a capacitor, connected in parallel, which produce an equivalent impedance.

2.6.6 *Interaction between circuits of an oscilloscope*

2.6.6.1 *Interaction between the circuits of a multitrace oscilloscope*

The influence of the voltage at one input on the deflection of a beam which is normally intended to display the voltage of another input.

2.6.6.2 *Interaction between x and y signals*

Under consideration.

2.6.6.3 *Decoupling factor*

Quantity defining the suppression of interaction between any two channels of an oscilloscope. It is the ratio between the unwanted deflection coefficient (i.e. the ratio between the amplitude of the signal of the disturbing channel to the unwanted deflection at the other channel) and the deflection coefficient of the disturbed channel.

Note. — The size of the decoupling factor is, therefore, in inverse ratio to the size of the disturbance. Decoupling factor is a number larger than 1. This means, accordingly, that the interaction corresponding to a factor of 10000 is smaller than that corresponding to a factor of 1000.
To simplify the interpretation of this definition, the following example is given: if the two channels are numbered 1 and 2, and have individual deflection coefficients of x V/cm and y V/cm respectively, then if channel No. 1 is considered as being the disturbing one and the magnitude of the display on trace No. 1 is A cm and if the magnitude of the display on trace No. 2 is B cm, the decoupling factor is given by the expression:

$$\frac{Ax}{By}$$

where normally $x > y$ and $A > B$.

2.6.6.4 *Phase difference between displays of a multitrace oscilloscope*

Phase difference (unwanted) observed between any two displays of a multitrace oscilloscope when the same signal is applied to both inputs.

Notes 1. — This difference may result from:
- different phase angle of the amplifiers,
- different linearity errors of the separate time bases,
- different geometrical structures of deflection plates.

2. — For test purposes, it is convenient to measure the phase difference in terms of time by applying the same pulse signal to both inputs.

2.6.6.5 *Common-mode rejection factor for difference amplifiers*

Relation between the deflection coefficient determined when a voltage is applied between the input terminals of the deflection circuit and the deflection coefficient determined when a voltage is applied between the input terminals, joined together, and the earth terminal of the oscilloscope.

Note. — The common-mode rejection factor is a measure of the ability of a circuit to reject interference and its size is, therefore, in inverse ratio to the size of the disturbance. Common-mode rejection factor is a number larger than 1, and a common-mode rejection factor of 10000 is larger than 1000. This means, accordingly, that the interaction with a common-mode rejection factor of 10000 is smaller than with a common-mode rejection factor of 1000.

2.6.7 *Delay line*

A transmission line having distributed or lumped constants intended to delay the signal.

Note. — The value of the delay is such that its duration is sufficient to allow the sweep to start and the spot to be unblanked before the signal is displayed.

2.6.7.1 *Apparent signal delay*

The time which elapses between the moment of the appearance of the sweep and the moment when the signal trace reaches 10% of the final amplitude.

Note. — The apparent signal delay is not to be mistaken for the actual signal delay which is the time elapsing between the application of a signal voltage at the input of the oscilloscope and the time of the appearance of the signal display on the screen.

2.6.8 *Switching rate (of multitrace oscilloscopes or associated plug-in units)*

The repetition frequency of the switching processes in oscilloscopes or associated plug-in units which employ electronic beam switching to produce multitrace displays. This frequency may have a fixed or adjustable value (chopped display) or may be controlled by the repetition rate of the time base and triggering (alternate display).

2.7 *Terms related to the time base*

2.7.1 *Time base*

The circuitry by which a spot displacement depending upon time is obtained.

Note. — The term "sweep" is reserved for the spot displacement produced by the time base.

2.7.1.1 *Free running time base*

A time base running periodically, even in the absence of a signal.

Note. — A free running time base may be synchronized either externally or internally.

2.7.1.2 *Triggered time base*

A time base which, for each single sweep, is initiated by a trigger pulse. The repetition rate is not necessarily periodic.

Note. — In this mode, any value of time coefficient can be chosen independently of the period of the observed quantity, and without affecting the stability of the display.

2.7.1.3 *Single sweep operation*

The operation of a time base in which one sweep only is triggered. Further sweeps are prevented until the sweep circuits have been externally reset.

2.7.1.4 *Hold-off circuit*

A circuit incorporated in the time base which prevents the sweep from being re-triggered until the spot has returned to its rest position and the circuit elements have completely relaxed.

2.7.1.5 *Delayed sweep*

A sweep which is started after a defined interval of delay following a triggering pulse.

2.7.1.6 *Delaying sweep*

A sweep produced by one time base of an oscilloscope when it is used to delay the start of another sweep (delayed sweep) produced by a second time base.

2.7.1.7 *Delayed sweep operation*

An oscilloscope function involving both a delaying sweep and a delayed sweep.

Note. — A common use of delayed sweep operation follows the normal display of a signal using a particular time base. A special circuit enables the delayed sweep to be started at any (adjustable) point in time during the sweep of the first time base. A change in the operating mode of the time base then enables the signal to be displayed on a time scale, provided by the delayed sweep which may well have a much smaller sweep coefficient.

2.7.1.8 *Spot unblanking (or bright-up)*

The process by which the spot is kept visible during the sweep time only and is suppressed during flyback and the rest time.

Note. — Suppression may be achieved by beam current cut-off or by deflecting the spot off the screen.

2.7.1.9 *Brightness*

Under consideration.

2.7.1.10 *Luminance*

Under consideration.

2.7.1.11 *Information writing speed*

The display characteristic which is an indication of the maximum number of trace widths per second that can be photographically recorded and identified.

2.7.2 *Time coefficient*

The ratio between the time and the length of spot displacement, produced by the time base, occurring during this time.

Note. — Time coefficients are expressed in the dimension time per unit length. This means, accordingly, that a sweep with a coefficient of 2 s/cm is slower that with a coefficient of 2 ms/cm.

2.7.3 *Expansion (or magnification)*

The process enabling the sweep to be increased in such a manner that a part of the display can be expanded so as to cover the whole rated horizontal deflection.

Note. — In general, this expansion is obtained by increasing the gain of the horizontal amplifier. The display will normally need to be recentred.

2.8 *Terms related to display stabilization*

2.8.1 *Display stabilization*

The process by which the sweep is made dependent on the observed phenomenon or on another related phenomenon, so as to bring the display to a standstill.

2.8.2 *Modes of stabilization*

2.8.2.1 *Synchronized sweep*

A recurrent sweep synchronized so as to maintain the sweep period equal to a period or multiple of the period of the observed quantity.

Note. — Synchronization is normally maintained for small changes in the period of the observed quantity.

2.8.2.2 *Triggered sweep*

The mode of operation of a triggered time base in which the beginning of every sweep coincides with a predetermined point of the displayed quantity, thus producing a stable display on the screen.

Note. — In triggered sweep modes, the internal trigger pulse can be produced corresponding to any predetermined level of the signal on either negative or positive going slopes.

2.8.2.3 *Internal synchronization (or triggering)*

The synchronization (triggering) obtained when the signal which controls the time base is supplied by an internal circuit affected by the observed quantity.

2.8.2.4 *External synchronization (or triggering)*

The synchronization (or triggering) obtained when the signal which controls the time base is applied externally and independently of the internal circuit affected by the observed quantity.

2.8.3 *Synchronization (or triggering) frequency range*

The frequency range for which the internal or external synchronization (or triggering) circuits permit a stable display to be obtained.

2.8.4 *Synchronization or triggering threshold*

The minimum value of the synchronizing or trigger signal (external) or the minimum value of the vertical deflection (internal) which is necessary to obtain a stable display.

2.8.5 *Time base jitter*

An (unwanted) fluctuation in the position of the display or a part of it, in a direction parallel to the sweep.

Note. — This fluctuation may result from:
a) an unwanted change in the trigger delay;
b) an unwanted modulation of the spot velocity.

2.9 *Miscellaneous*

2.9.1 *Geometry and orthogonality errors and phase difference*

2.9.1.1 *Geometry distortion*

A distortion appearing as a deformation of the boundary of a display, as related to the limits of the measuring area. The distortion shall be contained between the limits of the measuring area and a concentric rectangle of which the dimensions are given by the manufacturer.

2.9.1.2 *Orthogonality error*

The complement to 90 degrees of the angle formed by a vertical and a horizontal trace, measured at the centre of the measuring area.

2.9.1.3 *Parallelism error of multitrace oscilloscopes*

With cathode-ray tubes having at least two completely separated deflection systems, it is the angle between two horizontal axes and between two vertical axes measured at the centre of the measuring area.

2.9.1.4 *Phase difference between vertical and horizontal axes*

Difference in the phase response of the vertical and horizontal deflection circuits of an oscilloscope, resulting in a departure from a purely straight line display when a sinusoidal wave is applied simultaneously to these circuits.

2.9.2 *Direct connections to tube*

Method of connection from the outside of the oscilloscope to the vertical (horizontal) deflection plates or to the electrode intended for intensity modulation.

2.9.3 *Windowing facilities*

Under consideration.

3. General test requirements

3.1 *General*

3.1.1 *Statement of limits of errors*

3.1.1.1 Limits of operating error (which apply under rated operating conditions) shall be stated.

3.1.1.2 Limits of intrinsic error (which apply under reference conditions) may be stated. In the absence of a statement, they are considered to be equal to the limits of the operating error.

3.1.1.3 Limits of influence error may be stated. It is particularly useful to state these limits when one influence quantity or influencing characteristic causes an important part of the operating error. It may also be of interest to state that certain environmental conditions do not contribute to the operating error.

3.1.1.4 Limits of variation may be stated when this standard explicitly permits it.

3.1.2 *Performance characteristics and performances to be verified*

The tests described in this standard are to be performed in order to verify compliance with the manufacturer's stated data. These tests apply to:

— vertical and horizontal deflection coefficients (Clause 5),
— time coefficients (Clause 6),
— display stabilization (Clause 7),
— other miscellaneous qualities (Clause 8).

The clauses specify the conditions under which tests shall be performed, such as values of influence quantities, voltages to be used, switch positions of amplifiers, attenuators, etc., as well as whether these tests are mandatory or not. Recommended test methods for the determination of errors in deflection and time coefficients and for determining the displacement of the display form the object of Appendices A and B.

3.2 *Combinations of an oscilloscope with different accessories*

3.2.1 When an oscilloscope can take one or more plug-in devices, the assembly comprising the given plug-in devices and the oscilloscope itself is considered as a whole and shall comply with the relevant requirements for errors and variations, as stated in the following clauses. When another plug-in device is substituted, the new assembly shall also comply with the relevant requirements for errors and variations.

Note. — Plug-in devices for special purposes, such as curve tracers, etc., are subject to a special agreement between manufacturer and user.

3.2.2 When an oscilloscope is supplied with a probe, the combination of oscilloscope and probe shall comply with all requirements stated in the following clauses.
When probes are supplied as separate items and are intended to be used in combination with various types of oscilloscopes, separate specifications for the probes and for the oscilloscopes are required, and these specifications should define the properties of any combination of probe and oscilloscope recommended by the manufacturer.

3.3 *Reference waveforms*

3.3.1 *Reference sine-waves*

The following sinusoidal waves are used, generally at reference frequency, for test purposes.

a) A sine-wave for which the coefficient β, as defined in Sub-clause 2.3.3.1, is equal to 0.01.

b) A sine-wave for which the coefficient β, as defined in Sub-clause 2.3.3.1, is equal to 0.05 but having a peak value not differing by more than 1% from $\sqrt{2}$ × the r.m.s. value.

c) A sine-wave for which the coefficient β, as defined in Sub-clause 2.3.3.1, is equal to 0.05 and having no special requirement concerning the peak value.

3.3.2 *Reference pulses*

Reference pulse characteristics are defined as a function of rise time (t_r) of the circuit to be tested (Sub-clause 2.6.3.2).

a) Short reference pulse
Half-amplitude duration equal to 2 t_r
Rise time: 0.1 ... 0.25 t_r
Maximum error in amplitude: ± 5%.

b) Medium reference pulse
Duration: 10 t_r
Rise time: 0.1 ... 0.25 t_r
Maximum error in amplitude: ± 5%.

c) Long reference pulse
Duration from 25 t_r to as long as is necessary for any particular test
Rise time: 0.1 ... 2.5 t_r
Maximum departure from a flat top: 0.5%.

The amplitude of the long pulse is defined in terms of zones of reference as shown in Figure 4, page 78. The point A is the centre of the pulse transition and the reference zones Z_1 and Z_2 each having a duration t_r, are disposed symmetrically about the centre at distances corresponding to a multiple of t_r, for example 25 t_r.

The maximum tolerance on amplitude is defined at these zones of reference and in the portions of the pulse adjacent and takes no account of the centre of the transition.

Note. — Any aberrations which are not symmetrical or which contain time constants of more than 0.25 t_r, and which exist in the period from Z_1 (point A $-$ $t_r/2$ or point A + $t_r/2$) to Z_2, add to the uncertainty of the measurement accuracy as though they represented a change in pulse amplitude of equal amount (see Figure 4).

3.4 *Conditions for test location*

Unless otherwise specified in this standard, the following conditions shall be maintained in the test location:

— temperature within the range of 15 °C to 35 °C,
— relative humidity within the range of 45% to 75%,
— air pressure within the range of 70 kN/m^2 to 106 kN/m^2 (525 mm Hg to 800 mm Hg),

— the oscilloscope shall be supplied with rated mains voltage and frequency.

Note. — The values indicated above should not be confused with those indicated in Table I, page 39, for reference conditions and test conditions.

4. General test procedure

4.1 *Test procedure*

4.1.1 The tests specified in the following clauses are type tests applicable to oscilloscopes which are new and ready for use, i.e. with covers and accessories, if necessary, fitted.

4.1.2 When carrying out type tests, each oscilloscope tested shall be subjected to each of the tests laid down in this standard, as applicable, and as agreed between manufacturer and user.

The sequence of testing is not indicated by the order of the clauses.

4.1.3 In general, measurements for verification shall be carried out with instruments which do not appreciably (or only calculably) affect the values to be measured. In principle, the errors in measurements made with these instruments should be negligible in comparison with the errors to be determined.

4.1.4 When the error of the instrument is not negligible, the following rule shall apply:

if an oscilloscope is claimed to have a limit of error of $\pm e\%$ for a given performance characteristic and the manufacturer uses for its checking an apparatus resulting in an error of measurement of $\pm n\%$, the error being checked shall remain between the limits $\pm (e - n)\%$;

likewise, if a user checks the same oscilloscope using another apparatus resulting in an error of measurement of $\pm m\%$, he is not entitled to reject the oscilloscope if its apparent error exceeds the limits of $\pm e\%$, but remains within the limits of $\pm (e + m)\%$.

4.2 *General conditions for test purposes*

Tests are carried out under the conditions given in the sub-clauses below, and if agreed between manufacturer and user, under that combination of conditions which may be expected to result in the maximum operating errors.

4.2.1 *Recommended standard values and ranges of influence quantities*

4.2.1.1 The reference values or ranges, the rated ranges of use and the limit ranges of operation, storage and transport for all influence quantities shall be stated and shall be selected by the manufacturer from one of the usage groups I, II or III in Clause 6 of IEC Publication 359, Expression of the Functional Performance of Electronic Measuring Equipment. Any exceptions to the values given there shall be explicitly and clearly stated by the manufacturer with an indication that they are exceptions.

4.2.1.2 The oscilloscope may correspond to one group of rated ranges of use for environmental conditions and to another group for mains supply conditions, but this must be clearly stated by the manufacturer.

4.2.2 *Preparation for tests*

Before tests are performed, the following shall apply:

— adjustments, if any, shall have been performed according to the manufacturer's instructions,

— before being switched on, the oscilloscope shall be in equilibrium with the temperature and humidity of the ambient air,

— the oscilloscope shall be operated at the rated supply voltage for a period equal to the warm-up time as indicated by the manufacturer,

— in the absence of any indication, this period shall be 1 h,

— after the warm-up time, further adjustment may be made by means of the appropriate controls in accordance with the manufacturer's instructions,

— unless otherwise specified, the controls for fine adjustment and sweep expansion, if any, shall be set to the position which the manufacturer has assigned for calibrated readings.

4.3 *Particular conditions*

The controls shall be set, and signals applied to the input, as indicated at the head of each of the applicable following sub-clauses.

When no indication is given for a control setting, it may be set to any suitable value. Unless otherwise specified, no signal is applied.

4.4 *Reference conditions*

For the purposes of tests on oscilloscopes, a selection of influence quantities and influence characteristics with their reference values and/or ranges is given in the following Table I. The values in Table I have been taken from Publication 359, Clause 6.

TABLE I

Reference conditions

Influence quantities or influence characteristics	Reference conditions		Tolerance on reference values permitted for testing purposes
	When the reference conditions are indicated	In the absence of indication	
Ambient temperature	20 °C, 23 °C, 25 °C, 27 °C	20 °C	± 2 °C
Ambient air relative humidity	45% to 75%		
Air pressure (altitude)	101, 3 kN/m^2 (760 mm Hg)		
Supply voltage	Rated voltage		± 1% for d.c. and a.c. r.m.s. ± 2% for a.c. peak
Frequency of a.c. supply	Rated frequency		± 1%
Electric field of external origin	Under consideration		
Magnetic field of external origin	Under consideration		
Waveform of a.c. supply voltage	Sinusoidal		Sub-clause 3.3.1*b*) β = 0.05 Difference between $\sqrt{2}$ × the r.m.s. value and peak-to-peak value to within ± 1%
Waveform of triggering voltage	Sinusoidal		Sub-clause 3.3.1*c*) β = 0.05
Ripple content of d.c. voltage	Value given by the manufacturer	Negligible	Peak-to-peak value ± 1% of rated voltage
Waveform of the measured signal	Sinusoidal		Sub-clause 3.3.1*a*) β = 0.01
Frequency of the measured signal	Reference value	1 kHz	± 2%
Intensity of the electron beam		Any value between acceptable contrast and marked defocusing	

4.4.1 *Rated conditions of use*

The rated range of use for each of the influence quantities should be specified by the manufacturer. The minimum requirements for the limits of the rated ranges of use are those given in Table II. The values in Table II correspond to Usage Group I of Publication 359, Clause 6.

TABLE II

Limits of rated ranges of use to apply in the absence of indication by the manufacturer

Influence quantity	Limits of the rated range of use
Duration of applied mains supply voltage	The end of the warm-up time and a time 1 h later
Mains supply voltage	± 10% for d.c. and a.c. r.m.s. ± 12% a.c. peak
Mains supply frequency	Rated value ± 5%
Ambient temperature	+ 5 °C to + 40 °C
Frequency of the measured signal	Refer to Sub-clause 5.3.1

4.5 *Determination of operating errors of oscilloscopes*

The operating errors are measured under rated operating conditions stated by the manufacturer.

— Deflection coefficients are measured over the central 80% of the rated deflection.

— Time coefficients are measured over the central 80% of the rated horizontal deflection.

— Linearity errors are determined by comparison between the average coefficient as specified above and the average coefficients determined for 10% of the rated deflection at each of the extremities of the measuring area.

4.6 *Determination of the influence errors and the variations of the vertical (horizontal) coefficient, of the time coefficient and of the zero stability*

The oscilloscope being operated under the reference conditions shown in Table I, the influence errors or variations are determined for each influence quantity successively. The tests are performed for those influence errors or variations only where the manufacturer has specified corresponding limits. For each test, one influence quantity only is varied from its reference value (or a limit of the reference range) to the limits of its rated range of use, the other influence quantities being kept constant at their reference values or within their reference range.

4.6.1 The influence quantity is varied according to the following sub-clauses:

4.6.1.1 When a *reference value* is specified, the influence quantity is varied between that value and any value within the limits of the rated range of use.

4.6.1.2 When a *reference range* is specified without limits being given for the corresponding rated range of use, the oscilloscope is exempted from test with regard to the influence error for the influence quantity being considered.

4.6.1.3 When limits of the *reference range and* of the *rated range of use* are specified, the influence quantity is varied between each of the limits of the reference range and any value of that part of the rated range of use which is adjacent to the chosen limit of reference range.

4.6.2 *Influence of the duration of applied mains supply voltage*

— Deflection coefficient: a minimum value.
— Time coefficient: a suitable value.
— Signal voltage: sinusoidal at reference frequency to produce 80% of the rated deflection.

Tests on the influence of the duration of the applied supply voltage are made immediately following the warm-up time.

The influence error of deflection and time coefficients is determined over a 1 h period.

The tests are made by applying the signal to be measured at the beginning and at the end of the 1 h period, for a time just sufficient for the readings to be taken and without further adjustment of any control other than recentring, if required.

4.6.3 *Influence of mains supply voltage*

— Deflection coefficient: minimum value.
— Time coefficient: a suitable value.
— Signal voltage: sinusoidal at reference frequency to produce 80% of the rated deflection.

The tests are made by increasing in less than 0.1 s the supply voltage by 10% from its rated value.

The following measurements shall be recorded:

1. *During the first minute*
— the maximum shift of the display,
— the maximum variation of the coefficients.

2. *After 15 min*
— the shift of the display,
— the variation of the deflection coefficient after recentring,
— the variation of time coefficient.

The same tests are then made for a reduction of 10% from the rated value of the supply voltage.

4.6.4 *Influence of mains supply frequency*

— Deflection coefficient: minimum value.
— Time coefficient: a suitable value.
— Signal voltage: sinusoidal at reference frequency to produce 80% of the rated deflection.

The influence errors of coefficients are recorded after recentring. The change of frequency will be made within 1 min and the readings are made 15 min after the beginning of the change, after recentring.

4.6.5 *Influence of ambient temperature*

— Deflection coefficient: minimum value.
— Time coefficient: a suitable value.
— Signal voltage: sinusoidal at reference frequency to produce 80% of the rated deflection.

The influence errors of coefficients are recorded before readjustment and after recentring.

The time for changing the temperature is not laid down. The reading shall be made when the oscilloscope is in the new thermal equilibrium.

4.6.6 *Influence of the frequency of measured signal*

The specification for the influence of the signal frequency is given in Sub-clause 5.3.1.

5. Errors or variations of deflection coefficients and instability of the spot position

5.1 *Errors or variations of deflection coefficients*

5.1.1 *Operating error of deflection coefficients*

— Deflection coefficient: all calibrated values.
— Signal voltage: sinusoidal at reference frequency to produce about 80% of the rated deflection.

The error shall not exceed the limit given by the manufacturer.

5.1.2 *Linearity error*

— Deflection coefficient: a suitable value.
— Signal voltage: as appropriate, e.g. as described in Appendix A.

To be compared:

a) The average deflection coefficient over the central 80% of the rated deflection.

b) The average deflection coefficients determined in either of the two extreme 10% regions of the rated deflection.

The differences shall not exceed the linearity error limits given by the manufacturer.

5.1.3 *Influence errors of variations of deflection coefficients*

The following tests are performed to determine:

— the influence of the duration of applied mains supply voltage (Sub-clause 4.6.2),
— the influence of mains supply voltage (Sub-clause 4.6.3),
— the influence of mains supply frequency (Sub-clause 4.6.4),
— the influence of ambient temperature (Sub-clause 4.6.5).

These influence errors or variations shall not exceed the limits given by the manufacturer.

5.1.3.1 *Influence of magnetic fields of external origin*

— Deflection coefficient: that which results in the maximum effect.
— Time coefficient: a suitable value.

The influence of an external magnetic field is expressed by the ratio of the vertical deflection L resulting from a sinusoidal induction to the rated vertical deflection V_n.

The frequency of the interfering field shall be equal to the rated mains frequency of the oscilloscope unless otherwise agreed upon between manufacturer and user. It shall generate in the absence of the instrument a flux intensity having an r.m.s. value 0.5 mT. In the space to be occupied by the oscilloscope, the value of the flux intensity shall not differ from this value by more than 10%.

The terminals of the oscilloscope being short-circuited, the latter is placed in the direction in which the effect is maximum. The ratio L/V_n shall not exceed the limit given by the manufacturer.

Note. — It should be appreciated that induction of a much greater value than that occurring in practice is used for this test, in order to produce a convenient observation.

5.2 *Instability of the spot position*

The instability of the spot position is determined for both the vertical and horizontal directions when the oscilloscope is operated under the reference conditions of Table I, page 39.

If the drift is included in the operating error, then it is not determined separately, whereas if it is specified separately, the following test shall be made:

5.2.1 *Drift*

The input terminals to the deflection circuits are short-circuited and the time base is made inoperative. The spot is then accurately focused and the oscilloscope is allowed to function for a period of 1 h. During this period the drift is recorded directly.

Note. — However, if an agreement between the manufacturer and the user allows direct access to the vertical and horizontal deflection plates, a suitable recorder may be connected to the vertical (horizontal) plates and the horizontal (vertical) plates may be disconnected.

The drift is determined for the specified terms.

From the record obtained, the long- and short-term drifts are measured as shown in Figure 5, page 78.

— *The long-term drift (a)* is determined over a 1 h period beginning immediately after the end of the warm-up time. The value of the peak-to-peak excursion so determined shall not exceed the value given by the manufacturer.

— *The short-term drift (b)* is determined during a one-minute period for which the instability is a maximum, in the course of 1 h. The maximum value so obtained shall not exceed the value given by the manufacturer.

Notes 1. — In general, short-term drift will be stated in millimetres, long-term drift in millimetres per hour. If values are stated in microvolts per millivolt (microvolts per hour or millivolts per hour), these values alwavs refer to the smallest deflection coefficient of the oscilloscope.

2. — In the measurement of both short-term and long-term drifts, periodic and/or random deviations should be ignored. It is, therefore, desirable that any instrument chosen to record the drift should have a time constant sufficient to minimize the effect of these quantities.

5.2.2 *Periodic and/or random vertical (horizontal) deviations (PARD)*

— Time coefficient: a suitable value.
— Signal voltage: none.
— Deflection coefficient: minimum value.

The terminals of the amplifier are left open and shielded.

The periodic and/or random deviations expressed as a percentage of the rated deflections shall not exceed the value(s) given by the manufacturer. In the case of amplifiers having variable bandwidths, this test shall be performed at the setting which causes the effect to be a maximum.

Note. — Measurements of PARD shall be performed during sufficiently short time intervals to exclude any effect by drift.

5.2.3 *Zero shift resulting from a change in supply voltage*

When the oscilloscope is subjected to the test described in Sub-clause 4.6.3, the display shift resulting from a change in supply voltage, measured during the first minute and 15 min after that change, shall not exceed the limits given by the manufacturer.

5.3 *Frequency response and rectangular pulse or square wave response*

5.3.1 *Response to the frequency of the signal*

— Deflection coefficient: minimum value.
— Signal voltage: sinusoidal, of variable frequency and of voltage necessary to obtain 80% of the rated deflection at reference frequency.

The maximum variation of the deflection coefficient is determined for changes of the frequency value between the reference value and any frequency lying between the limits of the ranges of use. These ranges are preferably:

a) The rated range of use within which the variation does not exceed the error limit of the deflection coefficient.

b) The extended range of use within which the variation does not exceed 10%.

c) The —3 dB bandwidth.

5.3.2 *Rise (fall) time and overshoot of a rectangular pulse*

— Vertical deflection coefficient: all values.
— Signal voltage: positive and negative going medium pulses as defined in Sub-clause 3.3.2*b)*.
— Signal amplitude: to give 80% of the total rated deflection after proper position of the display.

During the test, the impedance of the pulse generator and input circuit of the oscilloscope including the connecting cables shall be matched.

The values of rise (fall) time and overshoot, when measured according to the definitions of Sub-clauses 2.6.3.2 and 2.6.3.3, shall not exceed the limits given by the manufacturer.

Note. — The orthogonality error (Sub-clause 8.1.2) should be taken into account when determining the rise time.

5.3.3 *Pulse tilt*

— Vertical deflection coefficient: a suitable value.
— Signal voltage: long pulses in accordance with Sub-clause 3.3.2*c)*. The duration shall be given by the manufacturer and the rise time shall be negligible in comparison with the duration.
— Signal amplitude: to give 80% of the total rated vertical deflection.

The value of pulse tilt, calculated according to Sub-clause 2.6.3.4, shall not exceed the limits stated by the manufacturer.

5.3.4 *Other pulse distortions*

— Vertical deflection coefficient: all values.
— Signal voltage:

a) For pulse distortions *a, b, c, d* and *e* of Figure 3, pages 76 and 77: medium pulses according to Sub-clause 3.3.2*b)*.

b) For pulse distortions *d, e, f* and *g* of Figure 3, page 77: long pulses according to Sub-clause 3.3.2*c)*.

Signal amplitude: to give 80% of the total rated vertical deflection.

The maximum values of pulse distortions other than overshoot shall be less than the limits given by the manufacturer.

Notes 1. — In certain types of oscilloscopes, the frequency response curve may contain peculiarities which a test with a unit step does not render sufficiently evident.

An absence of anomaly can be ensured by applying to the oscilloscope a test signal comprising a square wave of variable frequency and short rise time (in the region of t_r, rise time of the circuit to be tested), but maintained constant. The square wave frequency shall be increased until the third harmonic falls beyond the upper limit of the —3 dB bandwidth, the rise time being maintained constant.

2. — The test for sustained step response is made according to Sub-clause 5.3.3 but with a long pulse of 1 min duration.

5.4 *Positioning*

5.4.1 *Range*

The manufacturer shall state the effective range of the positioning controls as a multiple of the rated vertical (horizontal) deflections.

5.4.2 *Influence of positioning on deflection coefficients*

Signal: sine-wave voltage, the display of which when brought to the centre of the screen has a peak-to-peak amplitude of about 20% of the rated deflection.

The measurement of deflection coefficients shall be carried out as follows:

	Setting of positioning controls	Display
Coefficient K_1	To bring the display to the centre of the screen	Centre of the screen
Coefficients K_2, K_3	At its extremes	Brought back to the centre of the screen by adding a d.c. voltage or a square wave of suitable value to the signal
Coefficients K_4, K_5	At settings corresponding to displacements of the rated height (width) of the display	

The maximum change in the deflection coefficient due to positioning given by the greater of the following ratios:

$$\frac{K_1 - K_2}{K_1} \times 100, \quad \frac{K_1 - K_3}{K_1} \times 100$$

shall not exceed the value given by the manufacturer.

5.4.3 *Influence of positioning on pulse response*

The test is performed as in Sub-clause 5.4.2, but with medium reference pulses according to Sub-clause 3.3.2*b)* used in place of sine-waves.

The manufacturer shall state the effect of the extreme range of the positioning controls on the pulse response.

5.5 *Values of the elements of input impedance*

The values of the elements of input impedance of each measuring circuit or probe shall not differ, at the reference frequency, from the rated values by more than the tolerance given by the manufacturer.

Notes 1 — At high frequencies, the values of the elements of input impedance may change to a sufficient extent to cause difficulties in using the oscilloscope. The manufacturer shall supply with the oscilloscope information showing the values of these elements as a function of frequency.

2. — When there is a possibility that negative resistance may appear at the input of measuring circuits or probes, the manufacturer shall state the limitations imposed on measurement.

5.6 *Interaction between circuits of an oscilloscope*

The interaction between circuits of an oscilloscope is defined by the decoupling factor. The measurement is made by successively taking each circuit as the disturbing one, the input terminals of the other circuits being left open but shielded.

5.6.1 *Decoupling factor of multitrace oscilloscopes*

	Disturbing circuit conditions	Disturbed circuit conditions
Deflection coefficient	Maximum value	That value which produces the maximum interaction
Time coefficient	A suitable value	
Signal voltage	Sinusoidal at frequencies corresponding to each of the limits of the bandwidth of the disturbing circuit and to a value to be given by the manufacturer. Voltage to produce 80% of the rated deflection	

The minimum decoupling factor determined during successive tests shall be not less than the value given by the manufacturer.

5.6.2 *Interaction between x and y signals*

Under consideration.

5.6.3 *Decoupling factor of single-trace oscilloscopes*

The measurement is made as in Sub-clause 5.6.1, but each of the inputs is successively considered as the disturbing one, the others having their terminals left open but shielded.

The minimum value determined for the decoupling factor shall be not less than the value given by the manufacturer.

5.6.4 *Phase difference between traces of a multitrace oscilloscope*

	First channel Second channel
Vertical deflection coefficients	Suitable values
Time coefficient	Minimum value
Signal voltage (both inputs)	Medium pulses according to Sub-clause 3.3.2*b)* applied equally and simultaneously to both inputs
Signal amplitude (both inputs)	To give 80% of rated deflection

The test is made for every possible combination of traces. The phase difference between the corresponding half-amplitude points of the pulses displayed on the two traces shall be less than the value indicated by the manufacturer in each case.

Note. — In the case of amplifiers using electronic channel switching, it is necessary to use external triggering unless the time base can be triggered internally from one of the two channels in use.

5.6.5 *Common-mode rejection factor with difference amplifiers*

Vertical deflection coefficient	Minimum value
Time coefficient	A suitable value
Signal voltage	Sinusoidal at reference frequency, according to Sub-clause 3.3.1*c)*
Signal amplitude	So as to result in approximately the same deflection when in-phase and common-mode voltages are applied in turn

The common-mode rejection factor shall be not less than that specified by the manufacturer.

The manufacturer shall also state the range of frequency and in-phase voltage for which a specified common-mode rejection factor is exceeded.

5.7 *Apparent signal delay*

— Deflection coefficient: a suitable value.
— Time coefficient: minimum value.
— Signal: positive or negative short pulses, according to Sub-clause 3.3.2*a)*, and amplitude: to produce 80% of the rated vertical deflection.

Apparent signal delay is measured as the horizontal distance between the start of the sweep and the point at which the start of the pulse display reaches 10% of its final amplitude. This distance is then converted into time by multiplication with the appropriate time coefficient.

The delay measured should be not less than that specified by the manufacturer.

6. **Time base**

6.1 *General*

Conditions for tests on the time base are similar to those for the deflection circuits. The test methods may, however, be different.

6.2 *Errors or variations of time coefficients*

6.2.1 *Operating error of time coefficients*

— Time coefficients: all calibrated values.

The operating error over the interval between 10% and 90% of the rated horizontal deflection shall not exceed the limit given by the manufacturer.

6.2.2 *Linearity error*

— Time coefficient: all calibrated values.
— Coefficients to be compared:

a) the average time coefficient measured over the central 80% of the rated deflection,

b) the average time coefficients determined in either of the two extreme 10% regions of the rated deflection.

The maximum error shall not exceed the limits given by the manufacturer.

Notes 1. — The rest position of the sweep (which can be found by temporarily increasing the intensity of the spot with the time base inoperative) should be positioned on the left-hand line of the graticule.

2. — Difficulties may arise at the highest sweep speeds because of the inaccuracy in the starting time of the time base and the inaccuracy in the rise time of the unblanking waveform which may make part of the first tenth of the trace unusable. The manufacturer shall specify the coefficient beyond which the requirement will not apply. In such cases, the non-linearity should be measured according to the manufacturer's instructions in the second 10% and ninth 10% of the rated deflection.

6.2.3 *Influence errors or variations of time coefficients*

The following tests shall be made to determine:

— the influence of the duration of applied mains supply voltage (Sub-clause 4.6.2),
— the influence of the mains supply voltage (Sub-clause 4.6.3),
— the influence of the mains supply frequency (Sub-clause 4.6.4),
— the influence of the ambient temperature (Sub-clause 4.6.5).

The influence errors or variations shall not exceed the limits given by the manufacturer.

6.3 *Expansion*

This test is performed when calibrated indications are assigned to the expansion control by the manufacturer and applies to all calibrated positions of that control.

When the expansion control is operated, the time coefficient is measured between the points corresponding to 10% and 90% of the rated horizontal deflection.

The error of the time coefficient shall not exceed:

— when no error limit has been stated for the expansion control, the error limit stated for the deflection coefficient,

— when an error limit has been stated for the expansion control, the error limit for the deflection coefficient plus the expansion error limit.

7. Display stabilization

7.1 *Determination of display stabilization performance*

The performance is defined for internal and external synchronization (or triggering) by:

— the synchronizing or triggering frequency range,
— the synchronizing or triggering threshold,
— jitter.

These values apply to the means by which the display is stabilized in these two cases:

— of a synchronized sweep,
— of a triggered sweep.

When an oscilloscope provides both of these facilities, tests are made for each of them.

7.2 *Display stabilization performance*

The tests to be performed are shown in Table III, page 59.

For the purpose of this sub-clause, a stable display is one which has no more jitter than that specified by the manufacturer.

7.2.1 *Determination of the limits of the synchronizing or triggering frequency ranges*

The frequency of a sinusoidal voltage applied to the input circuit shall be increased in a continuous manner until it is no longer possible to obtain a stable display. The frequency corresponding to this point is the upper limit of the range.

The lower limit is found in similar fashion by decreasing the frequency of the signal applied to the input circuit.

The frequency range between these limits, having no gaps or discontinuities, shall be not less than that specified by the manufacturer.

7.2.2 *Determination of the synchronizing or triggering thresholds*

The following signals are used to determine the thresholds for both internal and external triggering:

— sine-wave according to Sub-clause 3.3.1*c)*,
— short pulse according to Sub-clause 3.3.2*a)*,
— medium pulse according to Sub-clause 3.3.2*b)*.

The minimum values required to maintain a stable display should be not greater than those given by the manufacturer.

Note. — The desirability of a threshold test using short pulses will be reconsidered in a future edition.

TABLE III

Characteristics of synchronizing or triggering circuits

Sub-clauses	Quantity to be determined	Synchronization or triggering source	Signal voltage	Vertical deflection coefficient	Results
7.2.1 and 7.2.3	Limits of synchronizing or triggering frequency range and time base jitter	Internal	Sinusoidal voltage to obtain 25% of rated deflection	Minimum value	*f* min ... Hz *f* max ... Hz
		External[2]	Sinusoidal voltage of 1 V, peak-to-peak	Convenient value for observation	Jitter at *f* max ... %
7.2.2	Synchronization or triggering thresholds	Internal	Sinusoidal voltage at the frequency given by the manufacturer	Minimum value	... mm peak-to-peak
			Positive or negative medium pulses[1]		
			Positive or negative short pulses[1]		
		External[2]	Sinusoidal voltage at the frequency given by the manufacturer	Convenient value for observation	... V peak-to-peak
			Positive or negative medium pulses[1]		
			Positive or negative short pulses[1]		

[1] The repetition rate of these pulses is constant and may have any value between 50 Hz and 10 kHz as convenient and in order to ensure a sufficient brightness of the trace.
[2] For external synchronization or triggering tests, the same signal is simultaneously applied to the input of the vertical amplifier and to the input of the external synchronizing or triggering circuit.

7.2.3 *Time base jitter*

Tests are carried out in the conditions of Sub-clause 7.2.1, but with a signal having a frequency equal to the upper limit of the synchronizing frequency range and having a level sufficient to produce a vertical deflection of 25% of the rated height of the display on the minimum deflection coefficient.

The tests are carried out at the minimum value of the time coefficient which causes the fault to appear.

The time base jitter, expressed as a percentage of the rated horizontal deflection, shall, at the worst point of the display, not exceed the value specified by the manufacturer.

8. Miscellaneous

8.1 *Geometry, orthogonality error and phase difference*

8.1.1 *Geometry distortion*

The geometry distortion when determined according to the definition of Sub-clause 2.9.1.1 shall not exceed the limits given by the manufacturer.

Note. — When the measuring area is not rectangular, the manufacturer shall define a rectangle, taking the major dimensions of the measuring area.

8.1.2 *Orthogonality error in axial deflections*

This error is measured by applying two successive displacements, one of which is vertical and the other horizontal (Sub-clause 2.9.1.2).

In the case of a multitrace oscilloscope, which has a cathode-ray tube with a separate deflection system for each trace, the test is carried out on each of the traces.

The orthogonality error shall not exceed the limits given by the manufacturer.

Note. — An orthogonality error of 1 degree corresponds to a 1 mm displacement of the horizontal trace at a distance of about 5.7 cm.

8.1.3 *Parallelism error of multitrace oscilloscopes*

The test is carried out as described under Sub-clause 8.1.2, but the angles between the horizontal traces (vertical traces) are measured.

The parallelism error shall not exceed the limit given by the manufacturer.

8.1.4 *Phase difference between vertical and horizontal displays*

The determination of this phase difference is made by applying the same voltage to the terminals of the vertical and horizontal deflection circuits.

The test is made in the frequency range given by the manufacturer.

With no phase difference, a straight line will be observed on the screen.

With a phase difference, this straight line becomes an ellipse (Figure 6, page 79). The value of the phase difference is given by the formula:

$$\sin \phi = \frac{h}{H}$$

where:

h = part of the vertical axis within the ellipse
H = height of the ellipse.

The value so calculated shall be less than the value given by the manufacturer.

Note. — In the case of multitrace oscilloscopes, the requirements of Sub-clause 8.1.4 apply to each successive combination of the vertical and horizontal channels.

8.2 *Deflection coefficient of cathode-ray tube plates having direct access*

The deflection coefficients are tested in a similar way to that described in Sub-clause 5.1.1. The error shall not exceed the limit given by the manufacturer.

When terminals for both deflection plates are accessible, the measurement shall be made with a balanced voltage. The necessary voltage shall be applied as indicated by the manufacturer.

The tests will be performed for a deflection equal to 80% of the total rated deflection.

8.3 *Calibrating devices*

Tests on calibrating devices are performed under reference conditions and according to the instructions of the manufacturer. The accuracy of calibration shall be determined subsequently by checking the calibrated quantity according to the relevant sub-clause of this standard.

8.4 *Electromagnetic radiation from oscilloscopes*

The magnitude of external electromagnetic radiation from oscilloscopes is determined under the following conditions.

The oscilloscope is set up on an insulating support without any earth connection and is supplied with its rated voltage via a 150 Ω standard artificial mains network, according to IEC Publication 106, Recommended Methods of Measurement of Radiated and Conducted Interference from Receivers for Amplitude-modulation, Frequency-modulation and Television Broadcast Transmissions. The voltages across the terminals of this artificial mains network are measured by means of a receiver which is tuned to the fundamental frequency of the sweep generator or of any other known possible source of r.f. energy (e.g. the e.h.v. generator) or to one of its harmonics. The artificial mains network and the receiver are placed in the interior of screening cages which are connected to the earth potential of the test room.

Measurements shall be made for:

— the balanced and unbalanced interfering voltages injected into the mains network, by supplying the oscilloscope through a screened cable. One end of the outer sheath of the cable is connected to the enclosure of the oscilloscope and the other end to the earth of the test room,

— the unbalanced voltage resulting from direct radiation from the oscilloscope, by supplying the mains connection through an unscreened cable having a screened suppression filter at the point of entry into the oscilloscope. The screen of this filter is directly connected to the oscilloscope enclosure.

The values so determined shall be less than the value given by the manufacturer.

8.5 *Brightness*

Under consideration.

8.6 *Luminance*

Under consideration.

9. **Method of expression of oscilloscope characteristics**

The form of specification for oscilloscopes to be provided by manufacturers, especially in data sheets and catalogues, shall, as far as applicable, be made in accordance with this clause.

The detailed data contained in the technical specification shall be expressed in accordance with Clauses 5 to 8 of this standard.

When no limits are given with the value for a specified quantity, the value is considered to be approximate only.

List of technical data

Information to be provided			
Designation		Units	Remarks
9.1	*General*		
	Manufacturer		Name and/or trade mark
	Type		
	Purpose		Measuring/observation oscilloscope
	Number of traces		Single trace/multitrace Multi-beam tube Electronic switching
9.2	*Tube*		
	Manufacturer		Name and/or trade mark
	Type		
	Multi-beam tube		State whether multi-beam or split-beam
	Dimensions	mm	Diameter or diagonal of the face
	Measuring area	mm	Height, width
	Screen type		Fluorescent material and screen construction, aluminizing, etc.
	Total accelerating voltage	kV	
9.3	*Functional units*		
9.3.1	*Types of amplifiers*		For example: a.c., d.c., difference
	Types of attenuators		Resistive, resistive-capacitive, fine control
9.3.2	*Plug-in units and probes*		Types available and purpose In case of interchangeable units, data for every possible combination
9.4	*Warm-up time*	min	
9.5	*Operating conditions*		
9.5.1	*Supply*		a.c. or d.c.
	Reference voltage	V	or reference range
	Rated range of use	V ... V	
	Reference frequency	Hz	or reference range
	Rated range of use	Hz ... Hz	
9.5.2	*Ambient temperature*		
	Reference value	°C	or reference range
	Rated range of use	°C ... °C	
9.5.3	*Relative humidity*		
	Rated range of use	%	State if wider than 0% and 80%
9.5.4	*Pressure*	kN/m^2 (mmHg)	State if < 70 kN/m^2 (525 mmHg)
9.5.5	*Reference frequency of signal voltage*	kHz, MHz	
9.6	*Signal display*		

Information to be provided			
	Designation	Units	Remarks
9.6.1	*Deflection coefficients (vertical/horizontal):*	V/cm V/division	When the deflection coefficient is expressed in V/division or in cm/V, the manufacturer shall translate it into V/cm. Full range of values or minimum and maximum values
	● Limit of error	%	
	● Linearity error limit	%	
	● Limits of influence error of deflection coefficients due to:		Within the rated ranges of use
	— duration of applied supply voltage	%	
	— changes of supply frequency	% per Hz	
	— changes of ambient temperature	% per °C	
	— magnetic field of external origin	%	As a fraction of rated deflection
	● Variation limits of deflection coefficients due to:		
	— changes of supply voltage transient variation	%	For a 10% abrupt change during the first minute
	remaining variation	%	After 15 min
	● Maximum permissible voltage for all inputs	V	Without damage
9.6.2	*Instability of the spot position*		
	Long-term drift	mm/h	Also mV/h, μV/h
	Short-term drift	mm	Also mV, μV
	PARD	%	State as fraction of rated deflection
	Shift due to supply voltage change:		For a 10% abrupt change
	— transient shift	mm	During the first minute
	— remaining shift	mm	After 15 min
9.6.3	*Response*		
	Frequency ranges		
	— rated range of use	Hz	For specified variation (Sub-clause 5.3.1*a*))
	— extended range of use	Hz	For 10% variation (Sub-clause 5.3.1*b*))
	—3 dB bandwidth	Hz	
	Rise (fall) time	μs, ns	
	Overshoot	%	
	Pulse tilt	%	
	Sustained step response	%	
9.6.4	*Positioning (vertical/horizontal)*		The range of control as a multiple of the rated deflection For the effect of positioning, see Sub-clause 5.4
9.6.5	*Input impedance*	MΩ/pF	State details if variable or containing negative resistance
	Tolerance	%	At reference frequency
9.6.6	*Interaction*		
	Single-trace oscilloscopes:		For inputs as applicable Full conditions to be specified in accordance with Sub-clause 5.6
	— decoupling factor		
	Multi-trace oscilloscopes:		
	— decoupling factor		
	— phase difference	μs, ns	
	Difference amplifiers:		
	— common-mode rejection factor		
	— maximum in-phase signal	V	

Information to be provided			
Designation		Units	Remarks
9.6.7	*Delay line*		State if any and, if fitted, the type of construction design
	Apparent signal delay	μs, ns	
9.6.8	*Electronic switching*		
	Type of switching		Alternate, chopped
	Switching rate	Hz	
9.6.9	*Other facilities*		State as applicable
	Auxiliary outputs		
9.7	*Time base*		
9.7.1	*Sweep*		
	Manner of time deflection		For example: linear, logarithmic, sinusoidal
	Operating modes		Free running, triggered, single shot, etc.
	Hold-off circuit		State if any
	Delayed sweep		State if any
	Delaying sweep		State if any
	Trace unblanking (or bright-up)		State if any and whether by suppression or deflection of the beam
	Information writing speed	Trace widths per second	
9.7.2	*Time coefficients*		Full range of values or maximum and minimum values. Fine control
	● Coefficient error limit	%	
	● Linearity error limit	%	An additional statement is required when the linearity error is given according to Note 2 of Sub-clause 6.2.2
	● Influence error limits of time coefficients due to:		
	— duration of applied supply voltage	%	
	— changes of supply frequency	% per Hz	
	— changes of ambient temperature	% per °C	
	● Variation limits of time coefficients due to:		
	— changes of supply voltage:		For a 10% abrupt change
	— transient variation	%	During the first minute
	— remaining variation	%	After 15 min
9.7.3	*Magnification (expansion)*		
	Effect of control		Continuously variable or switched; calibrated
	Error	%	Additional or total
9.8	*Display stabilization*		
9.8.1	*Operating mode*		Synchronized sweep, triggered sweep internally and/or externally
9.8.2	*Synchronized sweep*		
	Synchronization frequency range	Hz ... Hz	State values for internal and external operation, if different
	Synchronizing threshold:		
	— for sinusoidal waves — for medium pulses — for short pulses	V peak-to-peak mm	External operation Internal operation
	Time base jitter	%	Of rated horizontal deflection

Information to be provided			
Designation		Units	Remarks
9.8.3	*Triggered sweep*		
	Operating mode		For example: normal, preset, automatic. State if different modes result in different operating values
	Trigger frequency range	Hz ... Hz	State values for internal and external synchronization, if different
	Trigger threshold:		
	— for sinusoidal waves — for medium pulses — for short pulses	V peak-to-peak mm	External triggering Internal triggering
	Time base jitter	%	Of rated horizontal deflection
9.9	*Miscellaneous*		
9.9.1	*Geometry distortion*	mm	
	Orthogonality error	deg	
	Parallelism error	deg	
	Phase difference between horizontal and vertical displays	deg	
9.9.2	*Additional controls*		
	Direct connections to tube		State if permissible and if positioning controls are still operative. State working voltages of the electrodes concerned
	— deflection plates		
	— deflection coefficient	V/cm	
	— input impedance	Ω/pF	
	— frequency range	Hz	
	intensity modulation		
	— frequency range	Hz	
	— unblanking voltage	V	
	— input impedance	MΩ/pF	
	Intensity modulation via amplifier		
	— unblanking voltage and polarity	V	
	— input impedance	Ω/pF	
	— frequency range	Hz	
	— d.c. coupled		State if so; if not, state time constant
9.9.3	*Calibration devices*		Amplitude, frequency, time
	Type of device		Mark generator
	Action of device		On vertical, horizontal deflections and sweep
	Accuracy	%	
9.9.4	*Electromagnetic radiation (radio interference)*		Determined according to IEC Publication 106
	Conducted interference:	V/m	
	— symmetrical		
	— asymmetrical		
	— radiated interference		
9.9.5	*Power consumption*	VA	Under reference conditions
9.9.6	*Graticule*		Internal, external
	Arrangement		Fixed, removable, rotatable, adjustable
	Size and engravings		
	Illumination		State how achieved

Information to be provided			
Designation		Units	Remarks
9.9.7	*Additional devices* For example: — CRT alignment — beam finder — digital indicating devices — display storage — sampling		State if any and give details as applicable
9.9.8	*Safety class*		According to IEC Publication 348. In case of Class I, state kind of earth connection
9.9.9	*Mechanical features*		
	Design		For example: portable, trolley mounting, rack mounting
	Dimensions	mm	Over-projections
	Mass	kg	Normal accessories included
9.9.10	*Cooling*		Natural/forced
9.9.11	*Valve/solid state device replacement*		State whether normal or selected

10. Marking

10.1 *Data presented on the cathode-ray oscilloscope*

Such data shall be in accordance with the following:

10.1.1 On the visible outer surface of the oscilloscope shall appear:

— the manufacturer's name and/or trade mark,
— the type or model designation,
— the rated supply voltage and, for an a.c. supply, the rated supply frequency.

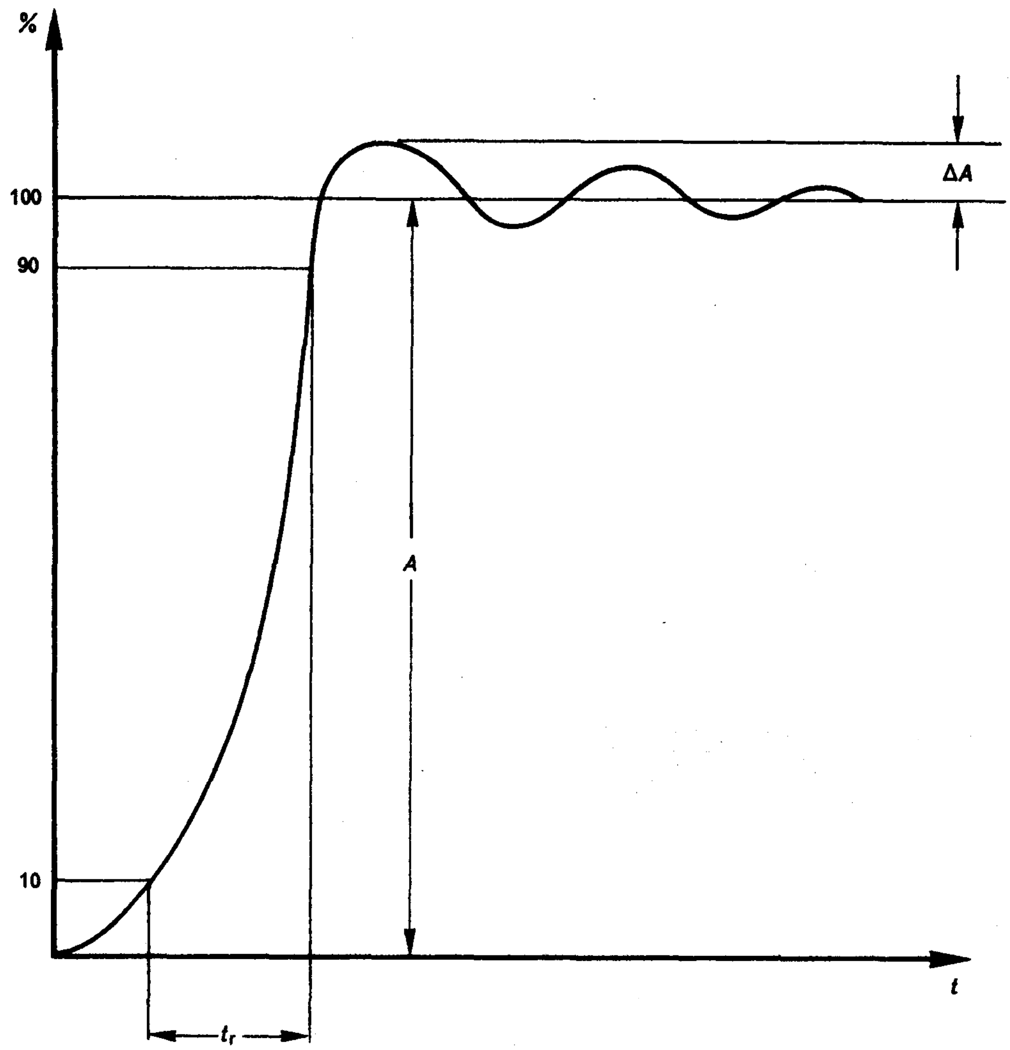
10.1.2 The rating and nature of the fuse shall be marked beside or on the fuse holder if replaceable fuses are used. If the oscilloscope is intended for several supply voltages and current ratings cannot be marked for lack of space, it will be sufficient if they are indicated in the instruction manual.

10.1.3 Terminals and operating devices shall be identified by one of the following methods:

— a marking stating clearly the intended purpose,
— an abbreviated marking corresponding to information in the instruction manual.

Terminals, in addition, shall, as far as possible, also be clearly identified as to impedance, polarity voltage and, if applicable, the form and magnitude of the signals to be applied or delivered.

Operating devices, in addition, should be equipped with a dial or scale to indicate clearly the values and/or operating modes obtainable in their different positions.



t_r = rise time

$\frac{\Delta A}{A}$ = overshoot

FIGURE 1

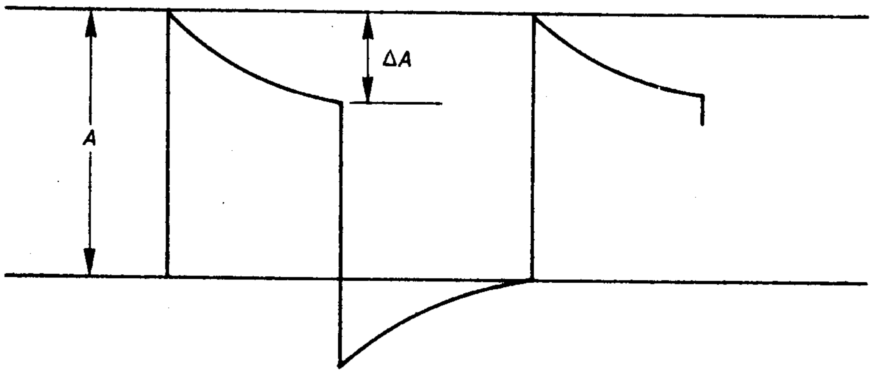


FIGURE 2a

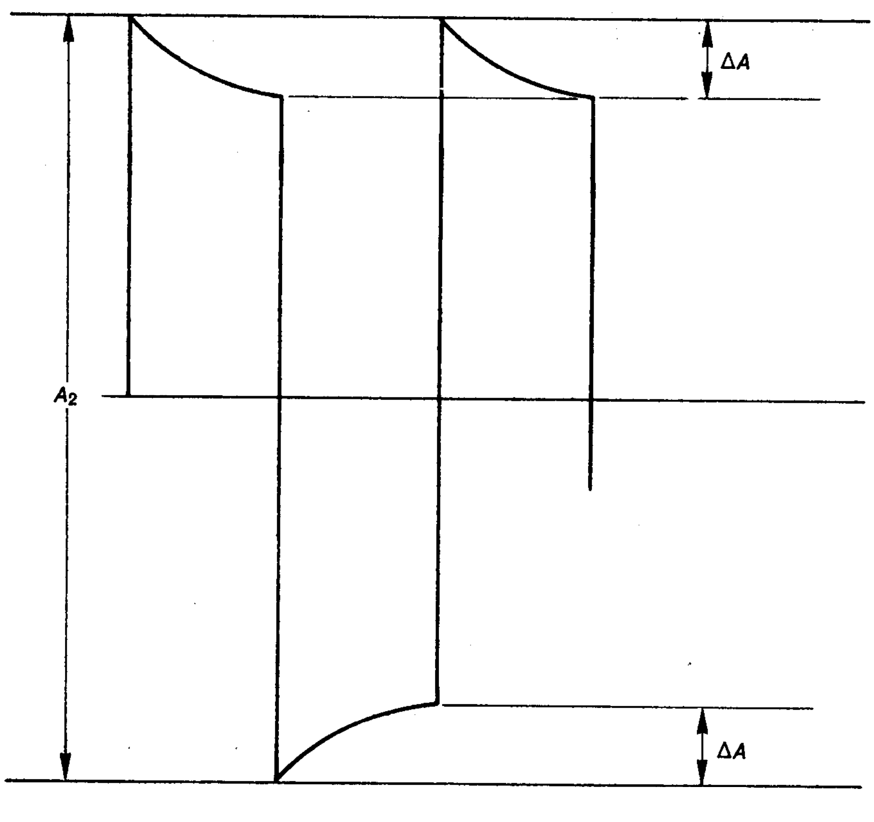


FIGURE 2b

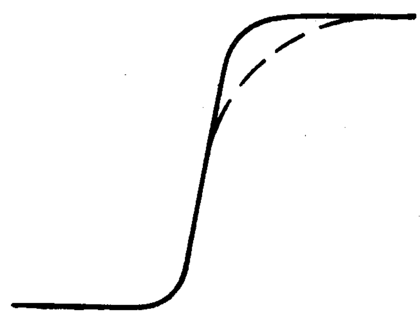
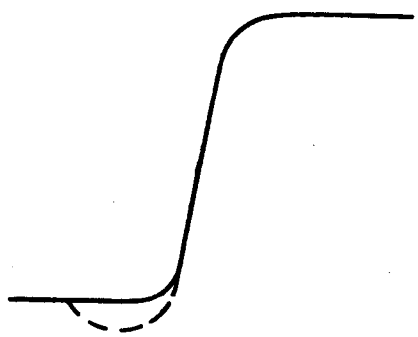


FIG. 3a. — Rounding



or

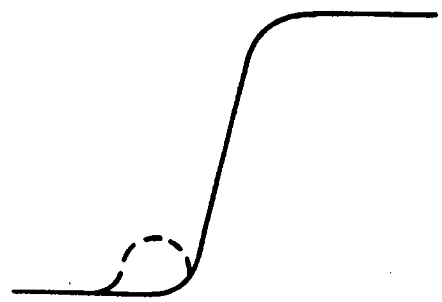


FIG. 3b. — Preshoot.

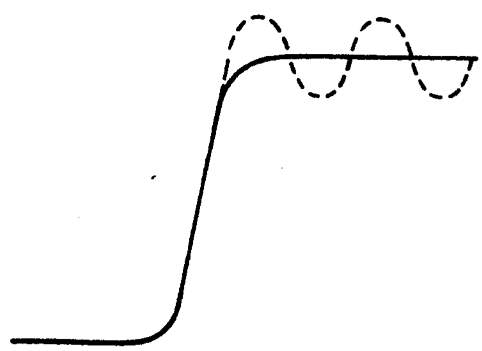


FIG. 3c. — Ringing.

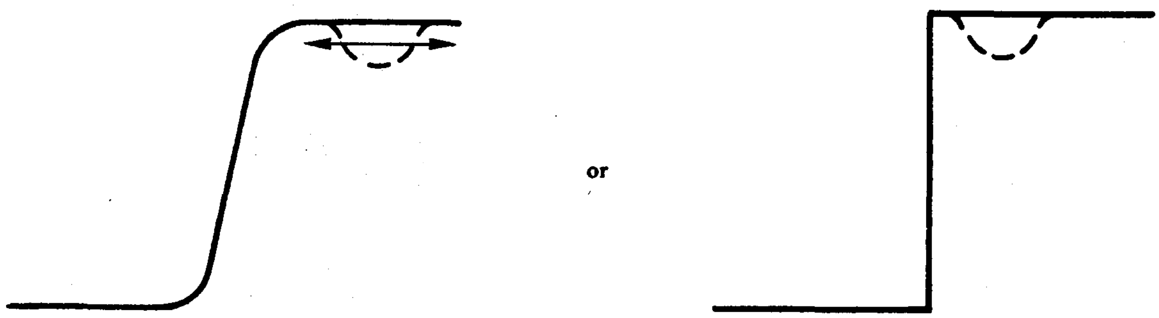


FIG. 3d. — Hole.

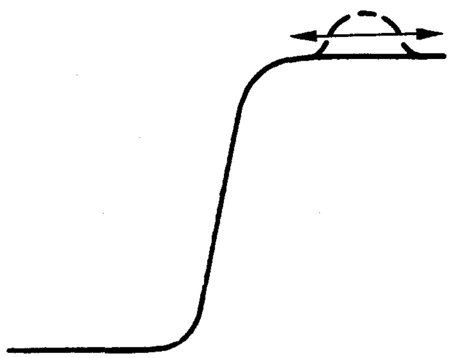


FIG. 3e. — Bump.

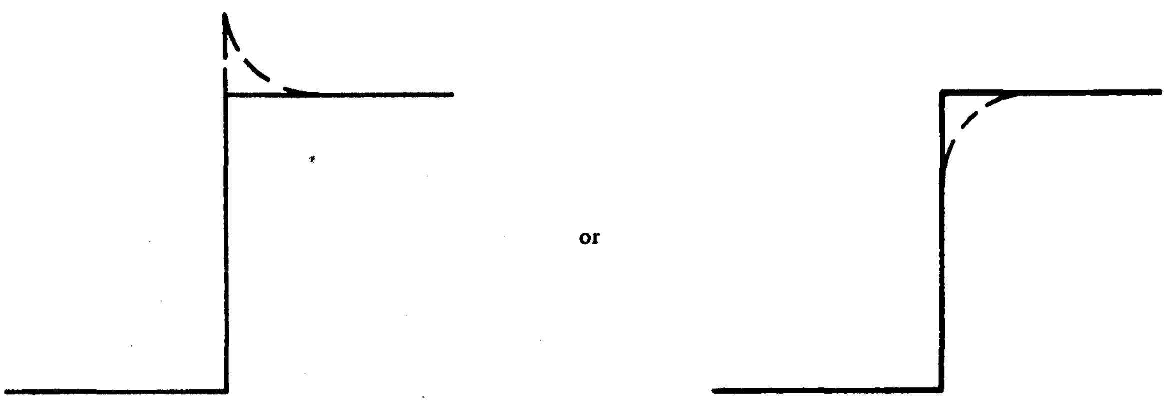


FIG. 3f. — Effect of maladjustment of the input attenuator.

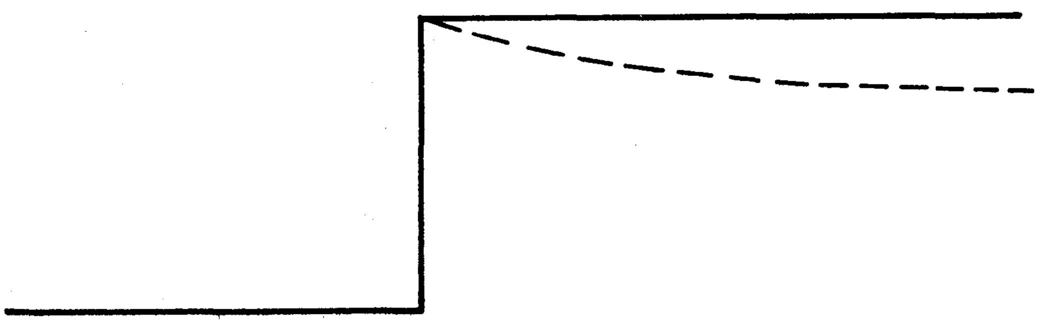


FIG. 3g. — Defect of sustained step response.

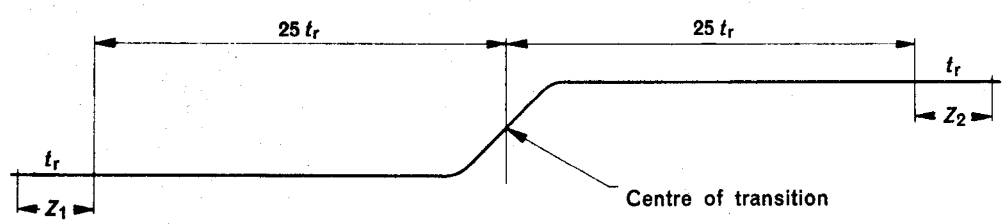
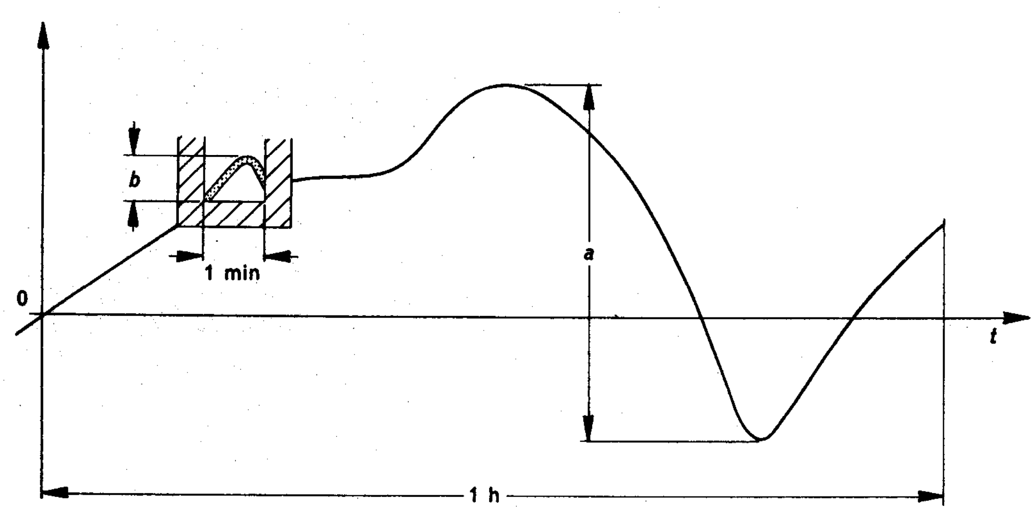


FIG. 4. — Long reference pulse.



a= long-term drift

b= short-term drift

FIG. 5. — Vertical (horizontal) drift

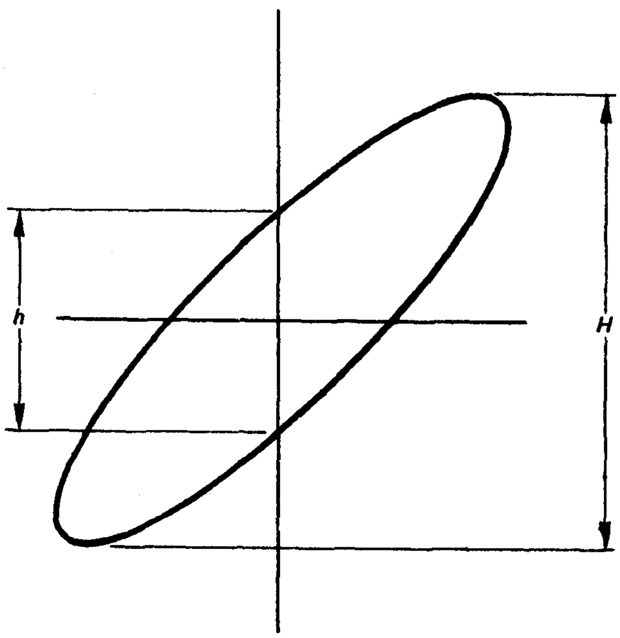


FIGURE 6

APPENDIX A

DETERMINATION OF (INTRINSIC, INFLUENCE, OPERATING) ERRORS OF DEFLECTION COEFFICIENTS AND TIME COEFFICIENTS AND OF LINEARITY ERRORS OF THESE COEFFICIENTS

INTRODUCTION

The means recommended for observing the trace are as follows:

a) The determination of errors in coefficients: direct visual observation by means of an anti-parallax lens mounted on the surface of the screen.

b) The determination of linearity errors in coefficients: a photographic recording.

A1 **Determination of errors of deflection coefficients**

A1.1 *Principle*

A sinusoidal voltage of reference frequency is used. To this voltage either a square wave of frequency equal to a sub-multiple of the reference frequency is added, or a variable direct voltage in the case of d.c. couple oscilloscopes, as required.

The signal so obtained is applied to the input of the oscilloscope.

With the square wave or direct voltage removed, the alternating voltage is displayed using a suitable time coefficient and is adjusted in amplitude so that its peaks coincide with graticule lines symmetrical about and parallel to the axis appropriate to the measurement.

The adjustment is made so that this coincidence occurs in accordance with Figure 7, page 90, the coincidence being observed through an anti-parallax lens.

If it proves to be impossible by these means to effect the necessary coincidence with symmetrically disposed graticule lines, it will be necessary to adjust the amplitude of the superimposed square wave or direct voltage in order to achieve coincidence without readjustment of the centring controls.

A1.2 *Measuring set*

The recommended measuring set is shown in Figure 8, page 91.

The square wave generator, which shall be synchronized with the sinusoidal voltage, may be replaced by an aperiodic scaling device having a ratio of 4, giving square signals.

The superimposing of the two voltages is effected by means of an adding network giving a sufficient decoupling between the two generators to eliminate the influence of the square signal on the indications of the voltmeter used for measuring the peak-to-peak value of the sinusoidal voltage.

A1.3 *Determination of the errors of deflection coefficients*

The oscilloscope being placed under general conditions as specified in Clause 4, the deflection coefficients are determined as follows:

A1.3.1 *Direct measurements*

The measurements are performed by operating the measuring set illustrated in Figure 8, and described in Sub-clause A1.2 of this appendix. The tests are performed according to the principle stated in Sub-clause A1.1 of this appendix.

The symmetrical graticule lines about the axis are those located at 10% and 90% of the rated deflection, as shown in Figure 9, page 92.

The tests are repeated, *without readjustment*, for every value of the deflection coefficients.

Note. — Generally, the determination of the errors of deflection coefficients is made only in the central vertical (horizontal) part of the measuring area, geometry distortion of the display being the object of the requirements provided in Sub-clauses 2.9.1.1 and 8.1.1 of this standard.

For each test, the value of the average deflection coefficient K_d is calculated from the peak-to-peak value of the voltage read on the voltmeter. The coefficient K_d may be different from its rated value K_{d0}.

The corresponding error ε_d, expressed in percentage, is given by the formula:

$$\varepsilon_d = \frac{K_d - K_{d0}}{K_{d0}} \times 100 = \left(\frac{K_d}{K_{d0}} - 1\right) \times 100$$

A1.3.2 *Indirect measurements*

Indirect measurements are applicable only to oscilloscopes in which it is possible to connect a voltmeter in the amplifier circuit beyond any attenuation device and on the condition that this connection does not disturb the normal operation of the oscilloscope.

This method, which has the advantage of allowing a reduction in the time required for testing, can only be used when there is an agreement between user and manufacturer.

It requires, in addition, a voltage divider calibrated with a precision that is sufficient in respect of the limits of error as specified by the manufacturer.

The measurements are performed in two phases:

— The first phase consists in using the method recommended in Sub-clause 1.3 of this appendix to determine the error ε_d of the deflection coefficient for which the position of the switch corresponds to minimum attenuation.

— In the second phase, the voltage divider is connected to the input of the oscilloscope and the voltmeter to the suitable point of the amplifier circuit of the oscilloscope.

By operating simultaneously the voltage divider and the switch controlling the deflection coefficients, the changes in voltmeter indication correspond to the intrinsic errors of the attenuator.

The error appropriate to each coefficient can then be obtained by taking the algebraic sum of ε_d and the change in voltmeter reading occurring for that coefficient switch position when expressed as a percentage.

Note. — The absolute errors of the voltmeter are of no importance, as relative readings in one range only are made.

A1.4 *Determination of the vertical (horizontal) linearity error*

The test is made by photographic recording and the measurements are made by enlarging the negative thus obtained.

Note. — The distortion introduced by the photographic devices shall be sufficiently small to be compatible with the errors to be determined.

The linearity errors are determined in the areas specified in Sub-clause 4.5 of this standard. However, the method is not strictly in accordance with the requirements specified in that sub-clause because the measurements are made on lengths and not on voltages. This shortcoming is of minor importance, unless the linearity errors are so large as to affect the results of the measurements significantly.

The tests are performed in three phases:

— *The first phase* consists in setting the adjustments of the measuring set shown in Figure 8, page 91, according to the principle stated in Sub-clause A1.1 of this appendix so as to obtain suitable values for the peak-to-peak amplitude of the sinusoidal voltage and of the amplitude of the square wave.

The process of adjustment consists of:

1. Obtaining on the screen a display of the sinusoidal wave sp that the peaks coincide with the 10% and 90% lines as shown in Sub-clause A1.3.1 of this Appendix.

2. Reducing the peak-to-peak value of the sinusoidal voltage to one-eighth of its original value and adjusting the amplitude of the square wave so as to bring the display of the reduced amplitude sinusoidal wave within the 90% and 100% graticule lines, the lower peaks being, if possible, tangential to the 90% line. This operation must be effected *without recentring.*

3. In readjusting the square wave to bring the display of the reduced amplitude sinusoidal wave within the 0 and 10% graticule lines, the upper peaks being, if possible, tangential to the 10% line.

— *The second phase* consists of photographing the different displays described above.

The above three adjustments are applied successively to the measuring set, prior to each photographic recording, so that the same negative contains the whole recording as shown in Figure 10, page 92.

— *The third phase* concerns the enlarging of the negative and the readings.

The negative is set in an enlarger, the overall scale of enlargement from the trace on the screen to the projected image being at least equal to three.

The enlarged image of the negative is projected against a screen on which lines corresponding to graticule line positions 0, 10%, 90% and 100% have been previously outlined, in accordance with the scale of enlarging. The axis perpendicular to these graticule lines is drawn in on the screen and is subdivided with elementary divisions between its intersections with the 0 and 10% lines and between the intersection with the 90% and 100% lines.
Such a screen is shown in Figure 11, page 93.

The scale of enlarging is then exactly adjusted so that the peaks of the enlarged central sine-wave coincide with the 10% and 90% lines, as shown in Figure 11. Measurement of the peak-to-peak amplitudes a_1 and a_2 of the two smaller sine-waves is made by means of the elementary divisions. If necessary, it is possible to move the screen slightly to make the peaks of these sine-waves coincide with the elementary divisions and so facilitate the readings.

The linearity error is equal to the difference between a_1 or a_2 and the quantity a, this being the interval between 0 to 10% or 90% to 100% lines. This error can be read directly from the elementary divisions.

A2 Determination of errors of time coefficients and of linearity errors of these coefficients

A2.1 *Principle*

Measurements are made of the time taken by the spot to cover, under the action of the sweep considered, a specified horizontal interval when a sinusoidal voltage (pulses) of defined amplitude and frequency is (are) applied to the input terminals of the vertical amplifier.*

* The choice between a sinusoidal voltage and pulses is dependent on the sweep speed.

A2.2 *Measuring set*

The recommended measuring set is shown in Figure 12, page 94. Note should be taken of the use of a phase adjuster, the output voltage of which is applied to the external synchronization input terminals.

Note. — It is generally possible to avoid the use of a phase adjuster provided that adjustments to the trigger level and slope controls permit the display to be moved on the screen.

A2.3 *Determination of errors of time coefficients*

The oscilloscope being placed under the general conditions stated in Clause 4 of this standard, measurement of the error in any of the time coefficients is made in accordance with Sub-clause A2.1 of this appendix (see Notes 1 and 2 of Sub-clause 6.2.2 of this standard).

When a sine-wave is used, its frequency is adjusted in order to obtain 20 to 30 periods of the sinusoidal trace on the measuring area. The sweep is synchronized externally from the sinusoidal voltage applied to the oscilloscope via a phase adjuster permitting the necessary horizontal movement of the display *without requiring any adjustment of the centring control.*

The phase adjuster and the generator are adjusted so that the vertical lines corresponding to 10% and 90% of the horizontal deflection coincide with the peaks of the sinusoidal trace.

This coincidence is observed through the anti-parallax lens.

This rest position of the spot, as defined in Sub-clause 6.2.2 of this standard, should be made to coincide with the left-hand limit of the measuring area.

An analogous method is appropriate when pulses from a time marker generator are used.

The time necessary for the spot to go through the width of the display considered is deduced from the frequency f read on the frequency meter and from the number of periods n counted between the chosen vertical lines. The time t is:

$$t = \frac{n}{f}$$

The average time coefficient K_b between 10% and 90% of the rated horizontal deflection is given by the ratio:

$$\frac{t}{D_{80}}$$

D_{80} being the distance between 10% and 90% of the rated horizontal deflection. This value K_b may be different from the rated value K_{b0} of the time coefficient.

The error ε_b of the average coefficient considered, expressed in percentage, is:

$$\varepsilon_b = \frac{K_b - K_{b0}}{K_{b0}} \times 100 = \left(\frac{K_b}{K_{b0}} - 1\right) \times 100$$

The tests are repeated *without readjustment* for every value of the time coefficients.

A2.4 *Determination of the sweep linearity error**

The determination of the linearity error of a given time coefficient is made in the regions stated in Sub-clause 4.5 of this standard.

* This method is applicable only in the general case when the values of the sweep correspond to the requirements of Sub-clause 6.2.2 of this standard.

The signals from a time marker generator are used, having a repetition frequency such that, in principle, one pulse per division is obtained (e.g. for 1 ms/cm a repetition frequency of 1 kHz would be appropriate). A display similar to that of Figure 13, page 95, is obtained.

When a time marker generator is used, the function of the phase adjuster in Figure 12, page 94, may be more effectively performed by a simple RC integrati.ıg network.

The recording of this display is made by means of the procedure set out in Sub-clause A1.4 of this appendix. The errors in the coefficients in the extreme regions are determined by means of a template drawn or placed on the screen of the enlarging apparatus. The distance *(D)* between the two reference lines corresponding to pulses 2 and 10 is considered as a reference base (Figure 14, page 95).

The scale of enlarging the negative is adjusted so that the displays of the pulses 2 and 10 coincide with the reference lines.

Elementary divisions have also been drawn on the template in order to permit location of the displays of pulses 1 and 11.

It is sufficient to measure the distances d_1 and d_2 between the displays of pulses 1 and 2 and between pulses 10 and 11 respectively.

The linearity error is equal to the difference between d_1 or d_2 and the quantity equal to the actual interval between the 0 to 10% or 90% to 100% lines.

This error can be read directly from the elementary divisions.

Note. — The recommended measuring method does not comply exactly with the definition. In fact, a given quantity is applied and the deflection is measured whereas the quantity corresponding to a given deflection should be measured.
This is of no importance when the linearity errors are slight.

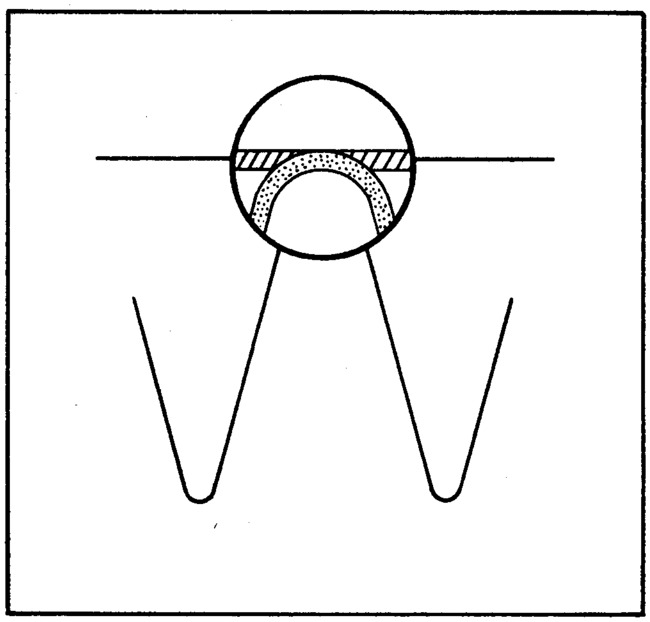
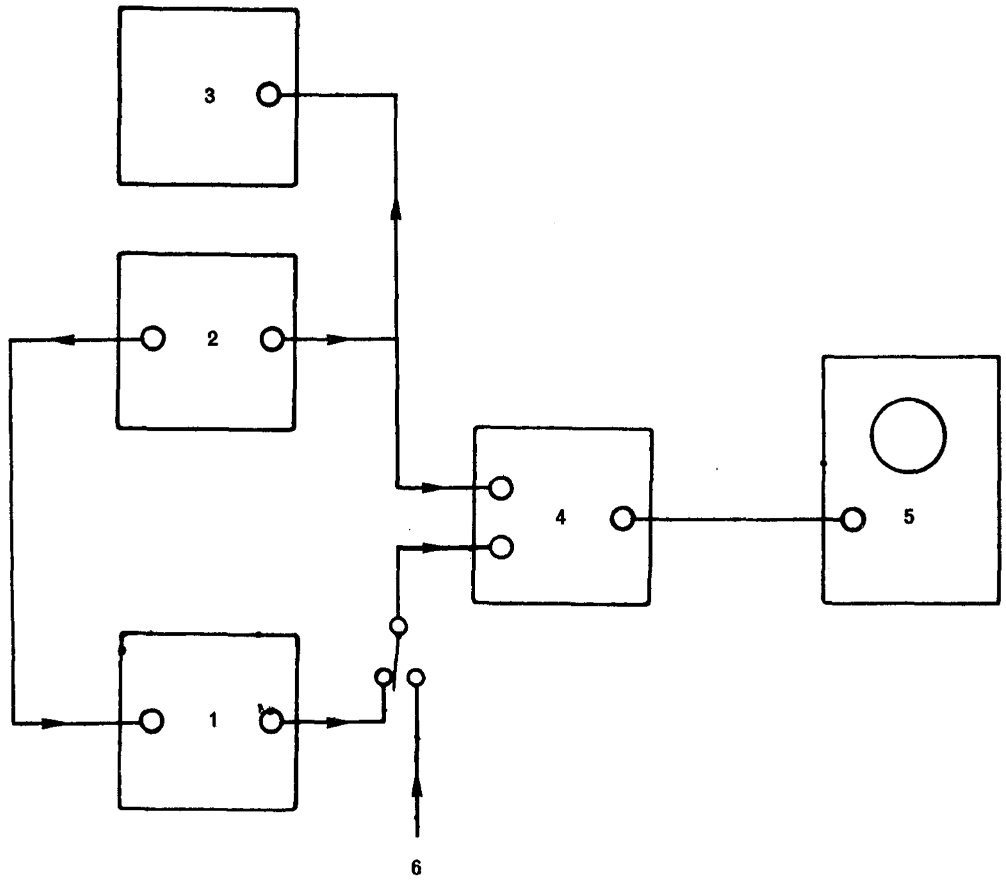


FIG. 7. — Determination of the Coincidence of a sine-wave with a graticule line by means of an anti-parallax lens.



1= square wave generator

2= sine-wave generator

3= voltmeter

4= adding network

5= apparatus to be tested

6= direct voltage

Note. — A sine-wave generator giving directly a calibrated voltage with the specified precision can also be used. In this case, the use of the voltmeter is no longer necessary.

FIG. 8. — Measuring set (deflection Coefficient).

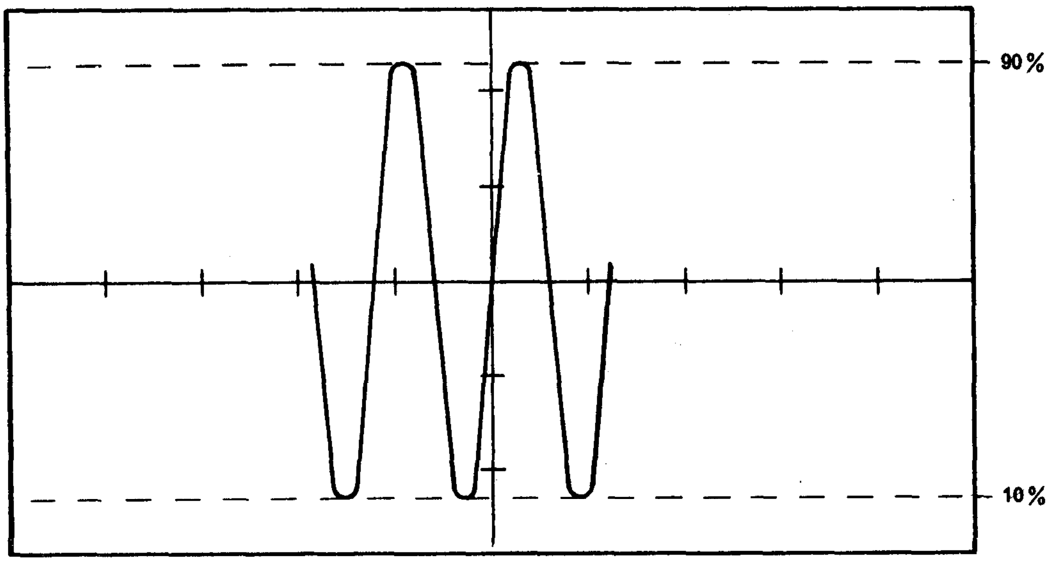


FIG. 9. — Measurement of the average deflection Coefficient.

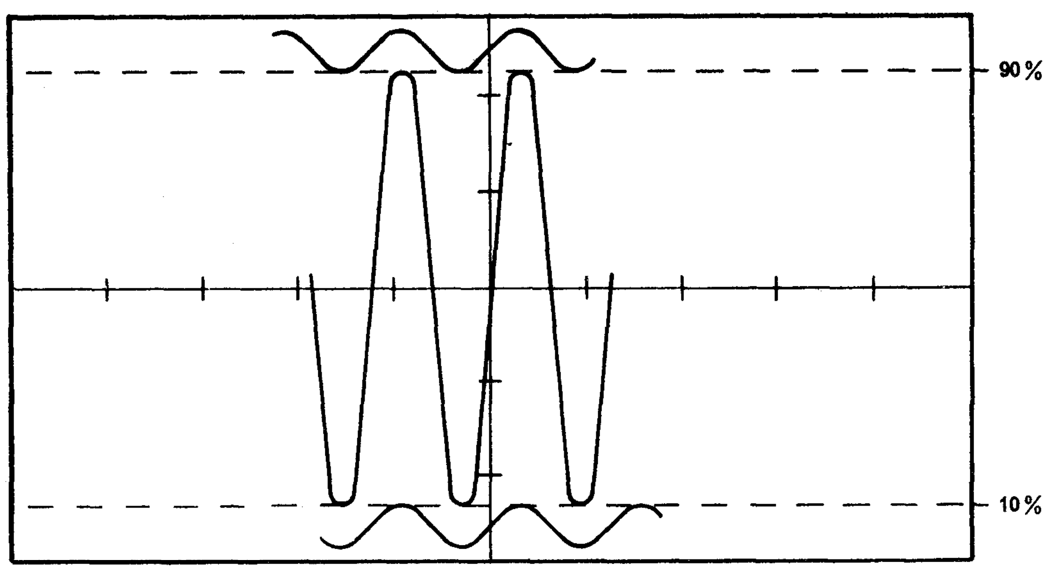


FIG. 10. — Error of linearity of the deflection coefficient.

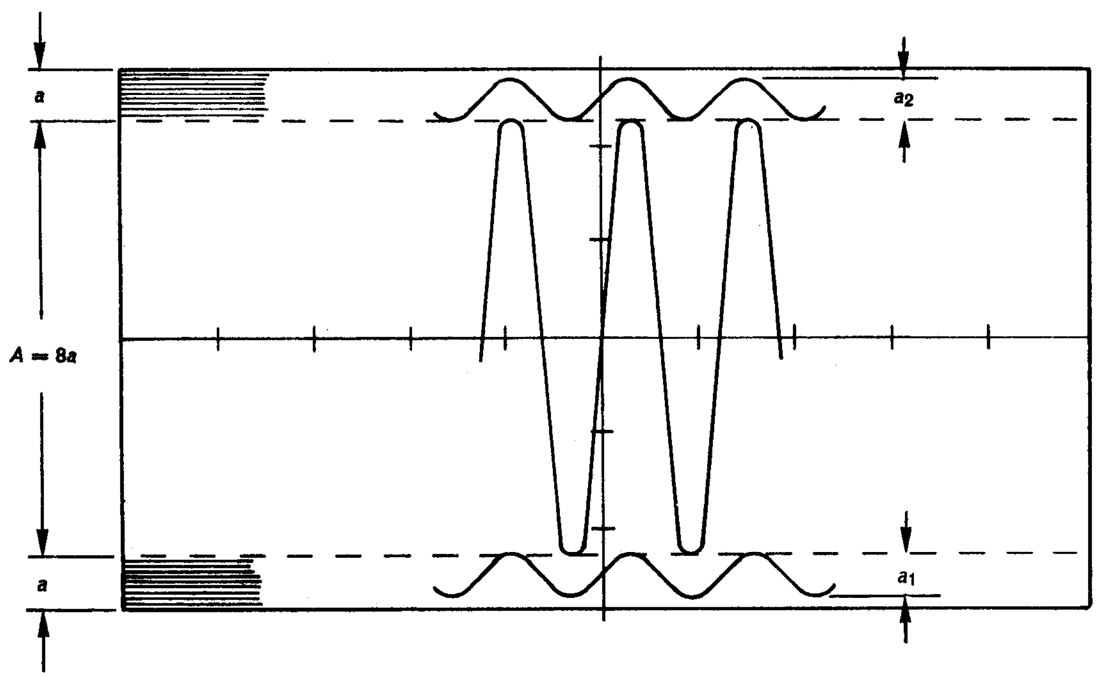
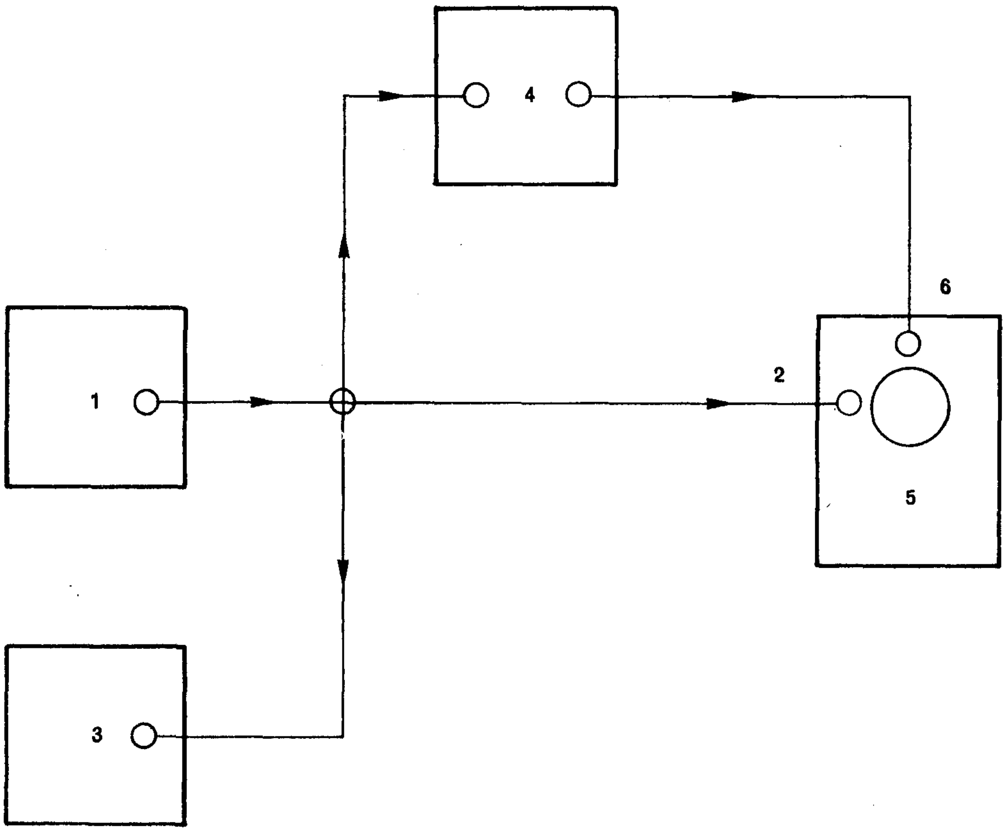


FIG. 11. — Error of linearity of the deflection Coefficient.



1 = Generator

2 = vertical amplifier input

3 = frequency meter

4 = phase adjuster

5 = apparatus to be tested

6 = trigger input

FIG. 12. — Measuring set (time Coefficient).

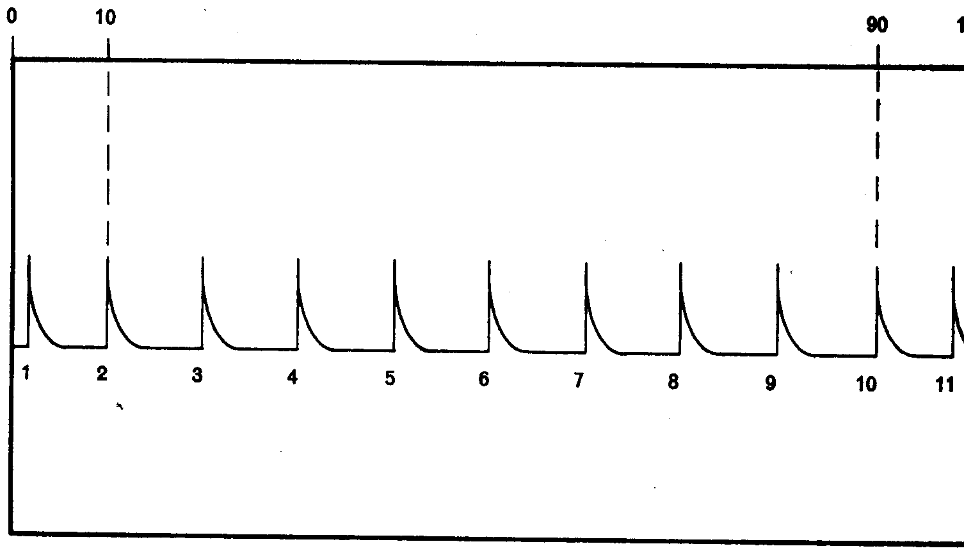


FIG. 13. — Display on the negative.

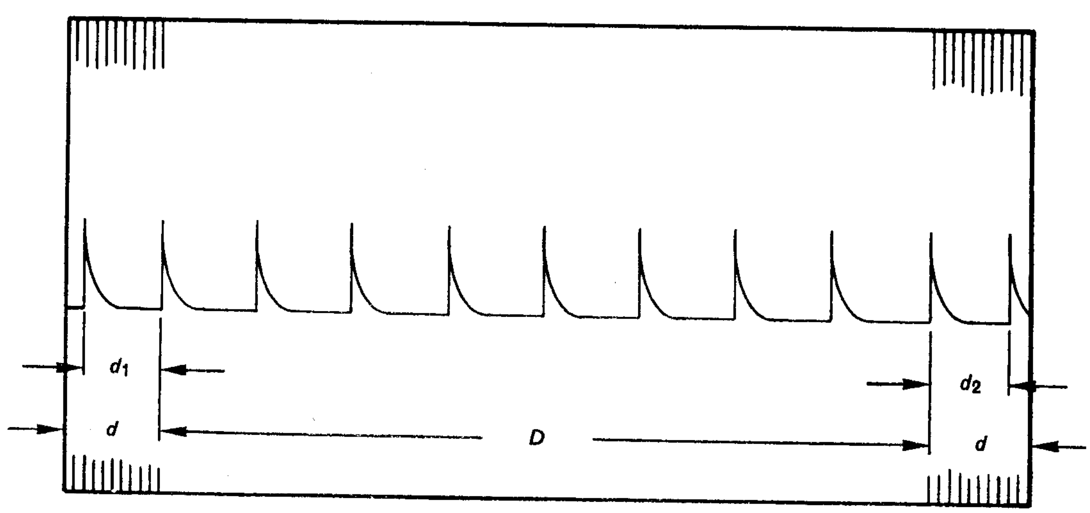


FIG. 14. — Display on the template set on the screen of the enlarger.

APPENDIX B

INFLUENCE OF SUPPLY VOLTAGE ON THE VARIATIONS OF THE DEFLECTION AND TIME COEFFICIENTS AND ON THE ZERO SHIFT

B1 Object

The object of this appendix is to lay down a method for determining the variations resulting from changes of supply voltage according to the requirements stated in Sub-clause 4.6 of this standard.

B2 Determination of variations of vertical (horizontal) deflection coefficients and of the zero shift

B2.1 *Principle*

The oscilloscope being supplied with the rated supply voltage, a square wave voltage, the frequency of which is about 1 kHz, is applied to the input terminals of the vertical (horizontal) amplifier. In the absence of a sweep, two points corresponding to the peak-to-peak amplitude of the square wave are obtained on the screen.

The value of the square wave being kept constant, the effect of changes in the supply voltage may modify:

— the distance between the two points, the change in which corresponds to that of the deflection coefficient,

— the position of the centre of this distance between the two points, the change of which is the displacement of the display.*

Successive positions of the groups of two points are recorded with respect to time, the camera, the shutter of which is operated periodically, being so placed that the unrolling of film is made orthogonally to the direction of the deflection considered. The same result could be obtained by means of a camera using continuously moving film.

Interpretation of the photographic recording is simplified if a mask is placed over the cathode-ray tube screen prior to the start of test, this mask having a slit wide enough to allow only the two points and small segments of the graticule lines on each side to appear. A series of pairs of points may then be obtained similar to the result shown in Figure 15, page 104.

B2.2 *Measuring set*

The recommended set for changing the supply voltage contains a transformer with a sliding contact. This contact may slide quickly between two steps previously adjusted so as to correspond to the required change of voltage. The time of travel from one step to the other shall be about 0.1 s.

B2.3 *Test*

The test is made with the minimum value of deflection coefficient. With the oscilloscope under the conditions stated in Clause 4 of this standard, a square wave is applied as indicated above in Sub-clause B2.1 of this appendix. Its amplitude is set to give a deflection going from 10% to 90% of the rated

* When it is possible to open the cover of the oscilloscope and provided that there is a suitable agreement between manufacturers and users, a d.c.-coupled chart recorder connected to the deflection plates of the oscilloscope may also be used for the measurement of the zero shift.

deflection on the screen. This amplitude is kept constant throughout the test. It is necessary to make sure that the changes of supply voltage do not give trouble due to changes in the brightness of the spot. Therefore, the adjustment of the brightness control made before the tests should take account of this.

The camera being set on the oscilloscope, successive operations are made as follows:

a) A first photographic exposure is made which will give, when examined, the initial positions of the peaks of the square wave with respect to which variations will be determined later (0 and 0′ being the corresponding reference points shown in Figure 15, page 104, and d_0 the distance between them. This distance will provide a reference for the subsequent determination of the variations).

b) The film is unrolled a few millimetres, by hand, unless a camera with continuously unrolling film is used.

c) A photographic exposure is made just after the 10% increment in supply voltage (instant $t = 0$ in Figure 15).

d) Successive photographs are taken during the first minute at suitable time intervals (e.g. 5 s). Before each exposure, the film is unrolled by an approximately constant increment sufficient to obtain distinct displays. The last photograph of the set is taken at the time $t = 1$ min.

e) A further exposure is made at the time $t = 15$ min (group pp′ in Figure 15).

f) After recentring and suitable film unrolling, a final photograph is taken (group qq′ in Figure 15).

After the supply voltage has been brought back to its rated value, the same exposures are made for a 10% decrement.

The film can then be developed.

B2.4 *Measurements*

B2.4.1 On the negative (see Figure 15), the following are noted for each set:

1. The distance d_0 between the two points 0 and 0′ registered before the instant $t = 0$.
2. The distance between two points among the pairs measured during the time interval $t = 0$ to $t = 1$ min and for which the influence is maximum (distance mm′ $= d_{max}$ or d_{min} as appropriate).
3. The maximum displacement Δ_{max} of the centre of the group of two points during the same period of 1 min.
4. The distance d'' between the points q and q′.
5. The displacement Δ of the centre of pp′ (last but one registered group).

B2.4.2 *a)* From these values are calculated:

— the greatest variation in deflection coefficient during the first minute, which is expressed in percentage by:

$$[\delta K_d]_{max} = \left| \frac{d_{max} \text{ or } d_{min}}{d_0} - 1 \right| \times 100$$

— the variation of the coefficient after recentring expressed in percentage by:

$$[\delta K_d]'' = \left| \frac{d''}{d_0} - 1 \right| \times 100$$

These values are those that are taken into account in Sub-clause 4.6.3 of this standard.

b) The greatest displacement Δ_{max} during the first minute and the greatest displacement Δ before recentring are those that are taken into account in Sub-clause 5.2.3 of this standard.

B3 Determination of the variations of time coefficients

B3.1 *Principle*

The oscilloscope being supplied at its rated voltage, a square wave is applied to the input terminals of the vertical amplifier of such a voltage that the peak of one excursion coincides with the horizontal axis of symmetry of the measuring area, the other being off the screen, and of a frequency such that the line obtained on the horizontal axis corresponds to the interval included between 10% and 90% of the rated horizontal deflection.

The successive positions of this line on the screen are recorded as a function of the time by means of a camera placed so that the film unrolls at 90° to the sweep direction. A set of lines, as shown in Figure 16, page 104, is obtained on the film.

B3.2 *Measuring set*

The recommended set is the same as shown in Sub-clause B2.2 of this appendix.

B3.3 *Test*

The test is performed with suitable values of deflection and sweep coefficients to obtain adequate definition at each end of the trace.

The oscilloscope is supplied with its rated voltage, the horizontal centring being readjusted if necessary.

A voltage having waveform and frequency as indicated in Sub-clause B3.1 of this appendix is applied to the input terminals of the vertical amplifier and is kept constant throughout the test.

Note. — It is assumed that the influence of the supply voltage on the time coefficient is independent of the value of this coefficient.

The camera being set on the oscilloscope, successive operations are made as follows:

a) A first exposure is made (Figure 16); this will give, when examined, the initial length b_0 of the display with respect to which variations will be determined later.

b) The film is unrolled for a few millimetres, by hand, unless a camera with continuously unrolling film is used.

c) A photographic exposure is made just after the 10% increment in supply voltage (instant $t = 0$ in Figure 16).

d) Successive photographs are taken during the first minute at suitable time intervals (e.g. 5 s). Before each exposure, the film is unrolled by an approximately constant increment, sufficient to obtain distinct displays. The last photograph of the set is taken at the time $t = 1$ min.

e) A further exposure is made at the time $t = 15$ min (group pp′ in Figure 16).

f) After recentring and suitable film unrolling, a final photograph is taken (group qq′ in Figure 16).

After the supply voltage has been brought back to its rated value, the same exposures are made for a 10% decrement.

The film can then be developed.

B3.4 *Measurements*

On the negative, the following are noted for each set (Figure 16, page 104):

1. The distance b_0 between the points 0 and 0′ of the first display recorded before the instant $t = 0$.

2. The width b of the registered trace during the time interval $t = 0$ to $t = 1$ min the influence is maximum (distance mm′ $= b_{max}$ or b_{min} as appropriate).

3. The width b'' of the display qq′ recorded after recentring (last recorded display).

From the two recordings, the following are noted:

— the greatest b_{max} or the smallest b_{min},
— the b most different from b_0.

From these values are calculated:

a) the greatest variation of time coefficient during the first minute, expressed in percentage by:

$$[\delta \dot{K}_b]_{max} = \left| \frac{b_{max} \text{ or } b_{min}}{b_0} - 1 \right| \times 100$$

b) the variation of this coefficient after 15 min and after recentring, expressed in percentage by:

$$[\delta K_b]'' = \left| \frac{b''}{b_0} - 1 \right| \times 100$$

The maximum values so determined are those that are taken into account in Sub-clause 4.6.3 of this standard.

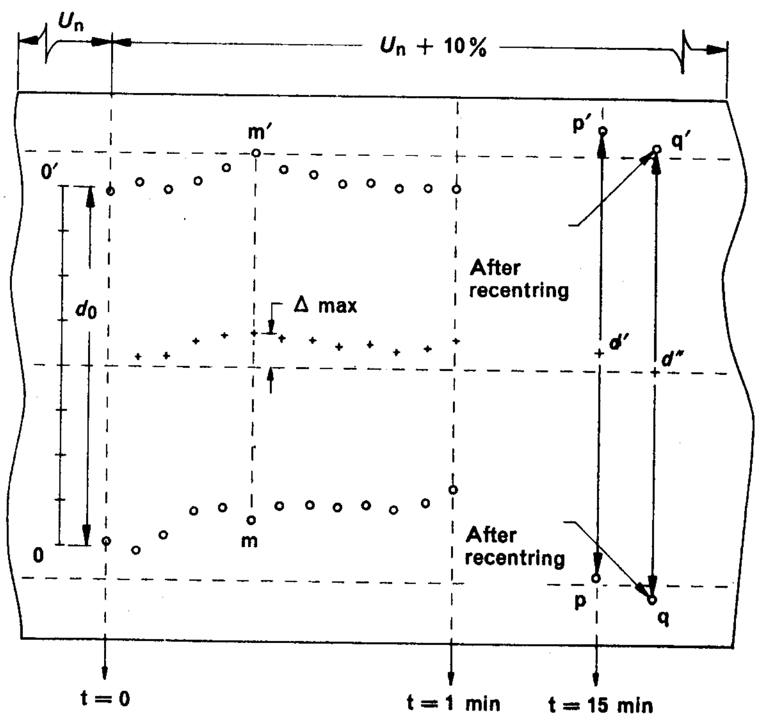


FIG. 15. — Variations of vertical (horizontal) deflection coefficient and zero shift

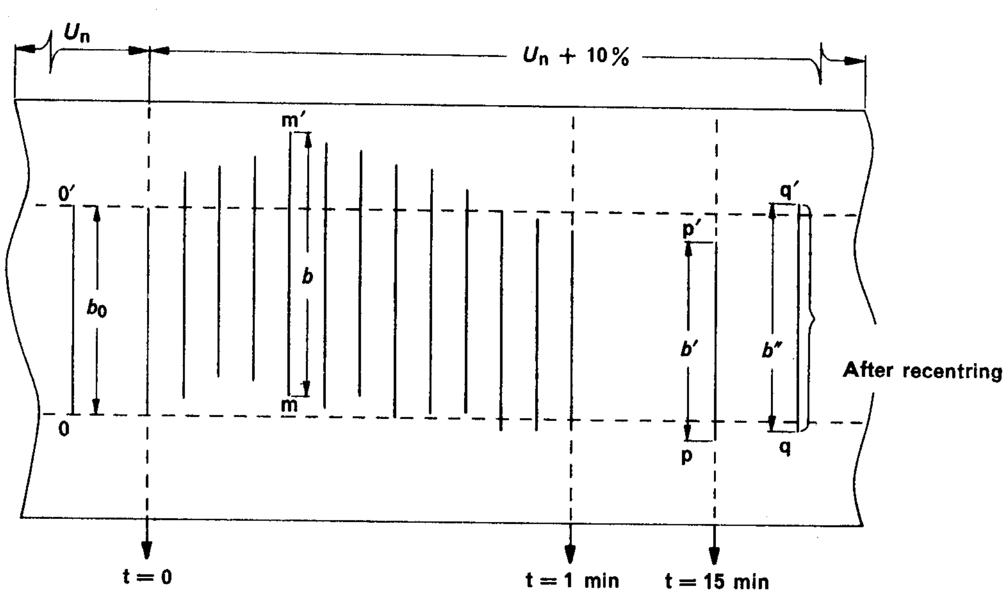


FIG. 16. — Variations of time Coefficient